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A range of designs has been developed to meet the needs of most ship types, crew sizes, trading patterns, stability criteria and sewage collection systems.

Construction, operation, maintenance and safety aspects are analyzed with a veiw to optimizing the economic impact on vessels that choose total retention as a method of satisfying the requirements of Great Lakes Sewage Pollution Prevention Regulations.

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DEVELOPMENT OF DESIGN GUIDELINES
FOR
SHIPBOARD SEWAGE HOLDING TANKS

by

German & Milne
Naval Architects

for the

Abatement and Compliance Branch
Water Pollution Control Directorate
Environmental Protection Service
ENVIRONMENT CANADA

Report No. EPS 3-WP-76-3
February, 1976

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Review Notice

This report has been reviewed by the Water Pollution Control Directorate, Environmental Protection Service, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

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ABSTRACT

This report presents a detailed study of shipboard sewage holding tanks suitable for vessels engaged on the Great Lakes - Lower St. Lawrence River trade route.

A range of designs has been developed to meet the needs of most ship types, crew sizes, trading patterns, stability criteria and sewage collection systems.

Construction, operation, maintenance and safety aspects are analyzed with a view to optimizing the economic impact on vessels that choose total retention as a method of satisfying the requirements of the Great Lakes Sewage Pollution Prevention Regulations.

RÉSUMÉ

Le présent rapport traite en détail des réservoirs d'eaux usées pouvant convenir aux navires qui sillonnent la voie commerciale des Grands lacs et du cours inférieur du Saint-Laurent.

On y présente une série de modèles qui répondent aux besoins de la plupart des types de bateaux, des équipages, des modes de commerce, des systèmes de récupération des eaux usées et qui sont conformes aux critères de stabilité.

Les aspects de la construction, du fonctionnement, de l'entretien et de la sécurité y sont analysés en vue de la plus grande économie possible dans le cas des navires conçus en fonction d'une rétention totale des eaux usées, afin de satisfaire aux exigences du règlement sur la prévention de la pollution par les eaux usées dans les Grands lacs.

TABLE OF CONTENTS

		Page
ABSTRACT		i
TABLE OF CONTENTS		iii
	List of Figures	v
	List of Tables	vi
CONCLUSIONS AND RECOMMENDATIONS		vii
1.	INTRODUCTION	1
1.1	General	1
1.2	Scope of Study	1
1.3	Terms of Reference	2
2.	GENERAL DESIGN CONSIDERATIONS	4
2.1	Sewage and Grey Water	4
2.2	Classification of Ships	6
2.3	Classification of Holding Tanks	6
2.4	Sub-Systems Considered	10
2.5	Recommended Sub-Systems	15
3.	DETAILED DESIGN OF HOLDING TANK SYSTEMS	17
3.1	Selection	17
3.2	Configuration	17
3.3	Capacity	18
3.4	Location	28
3.5	Structure	39
3.6	Effect on Stability	40
3.7	Protective Coatings	43
3.8	Piping and Pumping Detail	44
3.9	Shore Connection	48
3.10	Alarms and Indicating Devices	50
3.11	Controls and Electrical Installations	52
3.12	Nameplates	55
4.	OPERATIONAL AND MAINTENANCE PROCEDURES	62
4.1	Operation	62
4.2	Maintenance	62

TABLE OF CONTENTS (CONT'D)

Page

5. TESTING 64
5.1 Tank Pressure Test 64
5.2 System Running Test 64

6. ECONOMIC IMPACT 65
6.1 General 65
6.2 Capital Costs 65
6.3 Operating Costs 71
6.4 Maintenance Costs 74
6.5 Retrofit Costs 76
6.6 Grey Water 77
6.7 Summary Costs 78

DEFINITIONS AND ABBREVIATIONS 81

BIBLIOGRAPHY 84

APPENDIX I MARKET REVIEW 89

APPENDIX II STABILITY CALCULATIONS 93

APPENDIX III COST CALCULATIONS FOR HOLDING TANKS 99

LIST OF FIGURES

Figure		Page
1	Systems Configuration	9
2	Tank Configuration	19
3	Basic Flow Rates	24
4	Holding Tank Capacity Monograph	29
5	Laker	31
6	Tanker	32
7	Dredge (Large)	33
8	Passenger Vessel (Large)	34
9	Passenger Vessel (Water Bus)	35
10	Tug	36
11	Fishing Vessel	37
12	Dredge (Small)	38
13	Typical Construction Detail of Holding Tank - 100 to 900 Gallons	41
14	Typical Construction Detail of Holding Tank - 1,000 to 10,000 Gallons.	42
15	Sewage Diagram for Small Tank (900 gal and less)	46
16	Sewage Diagram for Large Tank (1,000 gal and up)	47
17	International Standard Shore Connection	49
18	Deck Discharge Station	51
19	Electrical Control Schematic	56
20	Electrical Power Schematic - Motor Starter	57
21	Electrical Power Schematic - Motor Starter	58
22	Electrical Block Diagram (System 'A')	59
23	Electrical Block Diagram (System 'B')	60
24	Electrical Block Diagram (System 'C')	61
25	Capital Cost of Tanks (Installed)	67

LIST OF TABLES

Table		Page
1	Classification of Vessels	7
2A	Flow Rates, Non-Passenger Ships	24
2B	Flow Rates, Passenger Ships	24
3	Holding Times	26
4	Capital Installed Costs of Holding Tank Systems (new Ships)	69
5	Capital Installed Costs of Direct Overboard Drain Piping (New Ships)	70
6	Shore Facility Fees Per Year	75
7	Summary of Costs for Holding Tank Systems for Typical Laker and Tug	79
8	Conventional Water Usage Holding Tank Effect on Static Stability	94
9	Low Water Usage Holding Tank Effect on Static Stability	95

CONCLUSIONS AND RECOMMENDATIONS

The results of this study may be summarized as follows:

1) Holding tanks should be constructed of mild steel, of rectangular shape with a hopper bottom.
2) All tanks should be fitted with exhaust vent, flushing system, discharge pumps and comminutors.
3) Tanks, if holding sewage for two days or more, should be fitted with aeration.
4) Tanks should discharge to shore connection station on deck, shore connection being to international standard.
5) Emergency overboard connection should be fitted with a blank flange to prevent accidental discharge.
6) Pump out and flushing system should be automatic in operation, once the pump has been started at the deck station.
7) Comminution and aeration sub-systems should run continuously once manually started.
8) Tank level alarms and malfunction alarms should be fitted.
9) Low water systems should be used to reduce capital costs.

1 INTRODUCTION

1.1 General

German & Milne, Naval Architects, have carried out this study on behalf of the Environmental Protection Service of Environment Canada, to assist ship owners in assessing the economic impact and design considerations for fitting shipboard holding tanks for the retention of sewage, with a view to subsequent discharge via a suitable shoreside reception facility.

This report is based on: a literature review pertaining to this subject; a market review of available equipment; discussions with suppliers of this type of equipment for the marine industry; an inventory of equipment fitted to existing vessels sailing the Great Lakes and St. Lawrence River; discussions and liaison with staff of the Environmental Protection Service and the Ministry of Transport; and finally, the experience and engineering judgement of the staff of German and Milne.

1.2 Scope of Study

This study is limited to holding tanks only and is not concerned with flow-through treatment devices, although it is recognized that in some cases the holding tanks will be fitted in conjunction with such devices.

Holding tanks have been considered for application to commercial vessels in service on the Great Lakes and St. Lawrence River. The problems associated with their application to government owned vessels and pleasure craft have not been addressed as they were outside the terms of reference of this study.

In order to ascertain the economic effect, both new construction and retroactive fitting costs have been analyzed, in addition to operating costs.

This report is intended to cover only the retention of human body wastes and associated flush waters. Brief comments and data have been included, however, to show the effects of retaining grey wastewaters.

1.3 Terms of Reference

The terms of reference as set out by the Environmental Protection Service were as follows:

The work will entail but need not be limited to:

(1) Waste holding capacity requirements for a vessel on a per man per day basis when used in conjunction with:

  (a) a low water usage sewage system;
  (b) a conventional water usage sewage system;
  (c) containment of sewage wastes and grey water wastes (galley, shower and wash basin drains).

(2) Estimation of costs involved for both new construction and retrofitting (cost range):

  (a) capital costs; and,
  (b) operating costs.

(3) Overall design requirements and limitations:

  (a) desirable configurations;
  (b) maintenance requirements, (access for cleaning, draining and flushing arrangements, etc.),
  (c) safety requirements (operational, procedures, explosion and health hazards);
  (d) desirable shipboard locations and areas to be avoided; and,
  (e) odour control system alternatives (including aeration etc.), also storage and handling arrangements for odour control chemicals.

(4) Associated piping and pumping system requirements:

  (a) vent and odour control piping;
  (b) effluent piping system;
  (c) influent piping system;
  (d) types of pumps and controls;
  (e) alarm and content instrumentation;

(f) preventive measures to be followed or equipment to be fitted to prevent accidental or unauthorized discharge over board; and,

(g) recommended size standards for shore discharge fittings recognizing existing Ontario and U.S. fitting standards.

In this connection basic diagramatic piping arrangements will be required.

(5) Alternate materials to be used in the construction of tanks, valves, pipes, pumps and fittings and protective coatings, etc., such as stainless steel, fibreglass, aluminium, plastic, etc.

2 GENERAL DESIGN CONSIDERATIONS

2.1 Sewage and Grey Water

In order to design holding tanks for the retention of sewage and grey water, the characteristics of both must be reviewed to understand the problems posed by their retention.

As defined at the end of this report, "sewage" means feces and urine and the associated flush waters. "Grey waters" means sink, shower, galley, laundry effluent, etc. Raw or "fresh" sewage is usually turbid and often contains many different types of solids, suspended and floating, such as paper, rags, garbage and feces.

Chemically, sewage is composed of some inorganic and many organic solids which are carried in water. In addition, the sewage contains dissolved gases and living organisms. Among the most important of these gases is oxygen, present in the original water supply and also dissolved from air in contact with the surface of the flowing sewage. In addition to dissolved oxygen, sewage may contain other gases such as carbon dioxide, nitrogen, ammonia, hydrogen sulphide and others. With respect to the living organisms, most of them are too small in size to be visible except with the use of a microscope. They are a natural living part of the organic matter found in sewage and they are important because they are one of the reasons for the success of our present biological treatment processes. The microscopic living organisms in sewage may generally be considered to consist of bacteria and viruses, some of which may be pathogenic, and other more complex higher forms of organisms. Fresh sewage normally contains from 10 to 200 million bacteria per 100 millilitres. Inorganic substances are recognized by the fact they are inert and generally not subject to decay or combustion. On the other hand, organic materials will decompose and are sometimes called volatile matter since they will burn when heated to high temperatures.

Inorganic and organic substances which can be seen in the sewage are known as suspended solids. These are the solids which can be removed from the sewage by physical or mechanical means, such as sedimentation or filtration. Those that cannot be readily seen are classified as dissolved solids. A third group called colloidal solids can be loosely described as very fine particles which are non-settleable. These may or may not be visible to the naked eye. The organic matter consists mainly of hydrogen, oxygen and carbon. These substances may be combined with fixed nitrogen, sulphur or phosphorus. The principle groups of these combinations are called proteins, carbohydrates and fats. These substances serve as food for bacteria and higher forms of organisms resulting in the decomposition or decay of the organic matter. Decomposition leads to the formation of carbon dioxide and water as well as some hydrogen sulphide gas. The organic strength of sewage is principally indicated by the amount of oxygen utilized as it undergoes decomposition. The standard parameter for indicating organic strength of sewage is biochemical oxygen demand (BOD).

As previously mentioned, fresh sewage contains an enormous number of bacteria. These are both aerobic and anaerobic in nature. If the characteristics of the sewage favour aerobic bacterial respiration then very little in the way of obnoxious odours will be evident. For this reason, many persons operating sewage holding tanks prefer to aerate or oxygenate the tank contents. If free air or oxygen is in short supply in the sewage, then the conditions become favourable for the production of anaerobic bacteria. Their rapid growth is characterized by the sewage colour turning black and the presence of sulphur type odours.

Any designer or fabricator of a sewage retention facility should make provision to minimize the problems associated with septicity. How this should be done will be discussed later in the report.

So far in this section, the discussion has dealt only with sewage. Grey waters may also be directed to such retention tanks along with the sewage. Grey waters for the most part simply dilute the sewage strength but will do very little to retard or reduce potential odour problems. Of course, the storage of these grey water effluents will require additional capacity to be designed into any retention system.

Grey waters, often coming from showers, etc. are usually warmer than ambient temperature. Since bacterial reaction rates increase with increased temperature, the storage of grey waters in the retention system may result in increased activity in the tank. If conditions in a retention system are aerobic then this increased activity will pose no special problems. However, if conditions are anaerobic, this potential increased activity could result in increased odour production.

2.2 Classification of ships

For the purposes of this study the ships trading the Great Lakes and St. Lawrence were considered as follows:

Cargo
Laker (bulk or package freighter)
Products tanker
Passenger
Large Ferry
Water bus
Fishing Vessels
Tugs
Dredges

These classes of vessels have generally the characteristics given in Table 1.

2.3 Classification of Holding Tanks

Holding tanks were considered according to capacity and further sub-divided as follows:

a) Tanks in conjunction with conventional water usage sewage systems.
b) Tanks in conjunction with low water usage sewage systems.
c) Tanks in conjunction with recirculating systems.
d) Tanks in conjunction with flow-through sewage treatment systems.

The question of capacity is of course related to number of crew and passengers, water usage, and holding time, which is related to time in port, length of voyage or time to get to the next suitable pump out facility or area where discharge is allowed via a sewage treatment

CLASS		APPROX OVERALL LENGTH (FEET)	Nº OF CREW	Nº OF PASS^{R}	FREQUENCY OF FUELING (DAYS)	ESTIMATED AVERAGE CAPITAL COST (DOLLARS)	SPACE AVAILIBILITY FOR HOLDING TANK
CARGO	LAKER	730	30		5 - 7	14,000,000	ADEQUATE
	PRODUCTS TANKER	370	30		5 - 7	7,000,000	ADEQUATE
PASSENGER	LARGE	330	60	400	5 - 7	10, 500,000	AMPLE
	WATER BUS	75	4	100	3 - 5	500,000	RESTRICTED
FISHING		70	2		3 - 5	100,000	RESTRICTED
TUGS		100	7		5 - 7	1,750,000	RESTRICTED
DREDGES	LARGE	240	30		5 - 7	10,000,000	AMPLE
	SMALL	65	2		3 - 5	750,000	AMPLE

TABLE I CLASSIFICATION OF VESSELS

system on board the vessel. For vessels which have space for larger holding tanks, the tanks may be sized so that pumping out is done at the same time as fuel replenishment, rather than at the next pump out facility.

Delays due to storms, ice, seaway traffic or other unforseen circumstances must be taken into account in arriving at the tank capacity.

The sub-systems for tanks with more than two days holding capacity should be as follows:

a) Conventional water usage systems
Tank will require exhaust vent and comminution/aeration systems. Capacity should be based on flow rates given in Section 3.3.

b) Low water usage system (vacuum system)
Tank will require exhaust vent and comminution/aeration systems. Capacity should be based on flow rates given in Section 3.3.

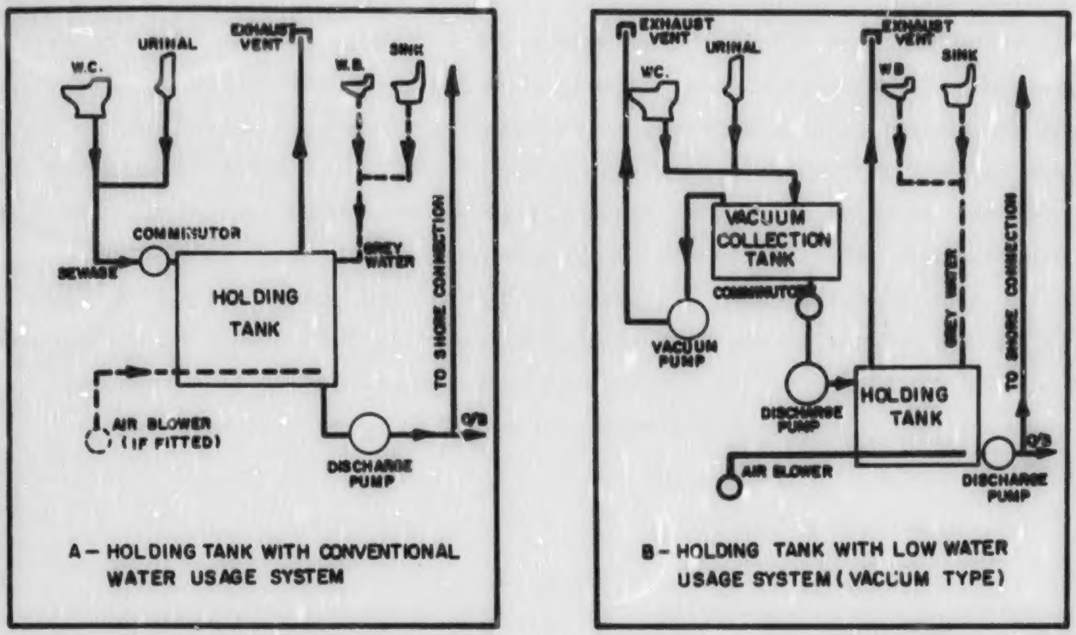
c) Recirculating system
Tanks will require exhaust vent only. Capacity should be based on flow rates given in Section 3.3.

d) Flow through system
Tanks will require exhaust vent only. Capacity should be based on flow rates given in Section 3.3.

For tanks with two days or less holding time, it has been assumed that the solids will not have time to really cake on the tank as the sewage will be relatively "fresh" and, therefore, a comminutor and vent only would be required. The tank would be based on the flow rates given in Section 3.3.

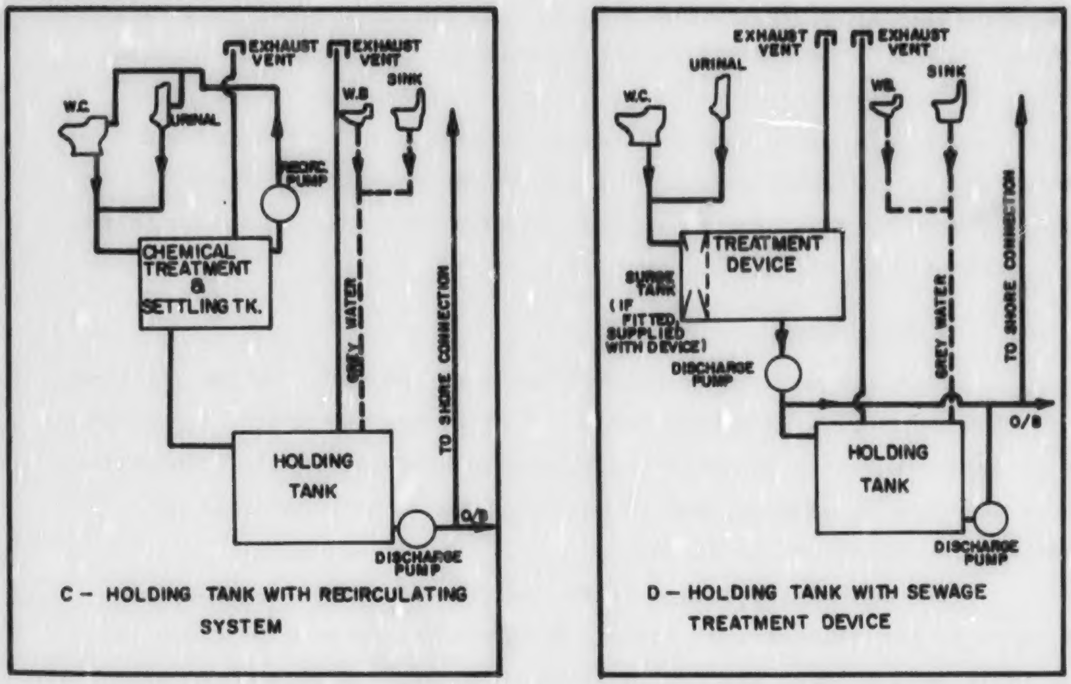
Figure 1 illustrates in simplified diagrammatic form the configuration of holding tanks associated with the various systems. The grey water lines, indicated as dotted lines from sinks and washbasins to the tanks, are of course optional features which the owner of the vessel may elect to have fitted.

It should be mentioned that, although a separate holding tank in conjunction with a vacuum type system is indicated, the vacuum system


W.C.
URINAL
EXHAUST VENT
W.B.
SINK
COMMINUTOR
SEWAGE
GREY WATER
HOLDING TANK
TO SHORE CONNECTION
AIR BLOWER (IF FITTED)
DISCHARGE PUMP
O/B
EXHAUST VENT
URINAL
W.C.
EXHAUST VENT
W.B.
SINK
VACUUM COLLECTION TANK
COMMINUTOR
VACUUM PUMP
DISCHARGE PUMP
HOLDING TANK
GREY WATER
TO SHORE CONNECTION
AIR BLOWER
DISCHARGE PUMP
O/B

A – HOLDING TANK WITH CONVENTIONAL WATER USAGE SYSTEM

B – HOLDING TANK WITH LOW WATER USAGE SYSTEM (VACUUM TYPE)


EXHAUST VENT
EXHAUST VENT
W.C.
URINAL
W.B.
SINK
RECIRC. PUMP
CHEMICAL TREATMENT & SETTLING TK.
GREY WATER
TO SHORE CONNECTION
HOLDING TANK
DISCHARGE PUMP
O/B
EXHAUST VENT
EXHAUST VENT
URINAL
W.C.
W.B.
SINK
TREATMENT DEVICE
SURGE TANK (IF FITTED, SUPPLIED WITH DEVICE)
DISCHARGE PUMP
GREY WATER
TO SHORE CONNECTION
O/B
HOLDING TANK
DISCHARGE PUMP

C – HOLDING TANK WITH RECIRCULATING SYSTEM

D – HOLDING TANK WITH SEWAGE TREATMENT DEVICE

FIG. 1 SYSTEMS CONFIGURATION

collection tank can itself be the holding tank. Where a large capacity is required it is more economical to keep them separate, the reason being that the vacuum tank is a pressure tank and therefore more expensive. Where the vacuum tank is used as the holding tank, it will not be necessary to fit the aeration system, as approximately 3 to 5 cubic feet of air per flush is drawn into the tank by the vacuum pump and the tank is vented via the liquid sealed pump. Figure 1 also shows the comminutor on the suction side of the vacuum tank discharge pump. If this cannot be arranged, it will be necessary to check with comminutor manufacturers to ensure that any comminutor fitted on the discharge side of the pump will work satisfactorily.

2.4 Sub-Systems Considered

When considering the design and installation of shipboard sewage holding tanks, the various alternatives which are available to reduce the probability and potential for producing odours and perhaps even explosive gases must be considered. At the same time, these alternatives must be acceptable from the maintenance and operational standpoint. Most of the alternatives considered involve the installation of sub-systems that are employed in the treatment of sewage at land based (stationary) facilities. The experience gained from these applications, however, can be applied to shipboard sewage holding tanks, with perhaps only slight modification.

2.4.1 Comminution

This system usually consists of a screen with cutting teeth or a grinder which cuts or grinds sewage as it enters the tank. Its purpose is to reduce the size of solids so that they are more easily transported, as in the case of pumping, and to make the sewage more amenable to chemical or biological treatment.

The main disadvantage of the unit is that, as a screen only, it tends to get blocked and requires frequent maintenance to clean it, and if it is a grinder unit it is prone to mechanical breakdown, also resulting in frequent maintenance. One point which should be mentioned here is that the solids are usually thought of as feces, but they can be much more - one supplier mentioned his unit had to deal with such items as underwear, pillow cases, towels, sanitary towels, nuts and bolts and such other miscellaneous items which had been forced down the toilet. A comminution unit may assist in some instances in shredding some items. The likelihood that it will get blocked, or the pipes will be blocked, before the item reaches the unit is not considered a valid reason for not fitting a comminutor.

The fitting of two units, one operating and one standby, helps to keep the process in continuous operation but is more costly and further complicates the holding tank because automatic changeover controls are necessary. Another way to alleviate the blockage problem is to fit the comminutor at the top of a tank recess which would form a trap to contain items which would block the unit, or alternatively to fit a bypass. Fitting the comminutor on the discharge side of the tank also helps in solving this problem, but then the unit is only assisting the effluent discharge and does nothing for the solids in the tank.

2.4.2 Aeration

As noted in Section 2.1, if sewage is decomposed aerobically, odours and harmful gases in significant quantities will not be produced. Therefore, if the contents of a holding tank are aerated to maintain a dissolved oxygen content in excess of 1.0 mg/l, the sewage will be kept aerobic and problems associated with the production of offensive odours and dangerous gases should be minimized.

The systems envisaged would supply air, under pressure, to raw comminuted sewage in the tank by means of the vessel's air compressor or by a separate compressor specifically installed for this purpose. Air would be piped into the tank and introduced through submerged diffusers and nozzles, carefully positioned to ensure that the tank contents are completely mixed and aerated. This is important from the operational and maintenance standpoint because the suspended solids should be kept in motion to prevent the formation of sludge deposits which may be difficult to dislodge when the tank is being pumped out and cleaned.

During the period of aeration, some treatment will be achieved and this, of course, will help to reduce the load on subsequent treatment systems that will eventually receive the effluent from the holding tank. However, it should be noted that the main purpose of aeration is not for treatment but rather to prevent the formation of undesirable odours and gases, to keep the solids in suspension, and to ventilate the tank thus forcing gases out of the exhaust vent.

The obvious disadvantage of aeration is the requirement for compressors when no other air supply is available, resulting in additionl power consumption and maintenance. Air nozzles and diffusers will also have to be maintained, which will involve periodic cleaning and possibly replacement. Maintenance can be reduced, however, by maintaining sufficient pressure at all times and using course-bubble diffusers and nozzles.

In recent years, increased interest has been shown in using pure oxygen instead of air in aeration systems. The advantages reportedly gained from such a system, however, would not be applicable to sewage holding tanks and therefore no further consideration in this context is warranted.

2.4.3 Chlorination

Chlorination of sewage has been widely used at many treatment plants for disinfection purposes and odour control. Chlorine is a strong oxidizing agent and is used for treatment of some industrial wastes and in particular for the oxidation of organic substances. Its chief use, however, is for disinfection and odour control and it has therefore been considered in relation to holding tanks.

Since chlorine will inhibit bacterial action, growth of bacteria is suppressed and the odours and gases associated with anaerobic decomposition are thus reduced or eliminated. However, if the chlorine residual is not great enough to inhibit bacterial growth and hydrogen sulphide is generated from anaerobic decomposition, the available chlorine may react with the hydrogen sulphide gas, forming free sulphur or sulphuric acid, depending upon the quantity of chlorine added. The sulphuric acid so produced can result in corrosion problems.

The most common chlorine chemicals used at wastewater treatment plants are compounds such as calcium hypochlorite and sodium hypochlorite or liquified chlorine gas. Calcium hypochlorite is available in either a dry or wet form and may contain as much as 70% available chlorine. Calcium hypochlorite pellets or granules are commercially available and, if stored in cool dry places, are relatively stable. Sodium hypochlorite is available in strengths from 1.5 to 15% in liquid form. However, the solution loses free chlorine rapidly at high concentrations and if affected by light and heat. Chlorine gas is supplied as a liquified gas under high pressure in containers but, for reasons of safety and difficulty in handling, it may not be advisable to use it in this form on board vessels. Disadvantages of using chlorination are obvious. Proper storage would have to be provided for the compounds and since chlorine solutions are very corrosive, they should be handled in rubber-lined or plastic piping with diffusers of hard rubber. In addition, equipment such as feeders must be maintained and the contents of the tank must be mixed to ensure chlorine contact throughout. Because of these disadvantages, chlorination to control odours and prevent the formation of gases is not recommended for holding tanks on board vessels.

2.4.4 Ozonation

Ozone, like chlorine, is a strong oxidizing agent and is used for odour control and disinfection. Although technically feasible for holding tank applications, the current costs associated with this form of odour control may be prohibitive in comparison to other systems that could be used to accomplish the same objectives.

2.4.5 Odour control chemicals

Chemicals other than chlorine may be added to sewage to control odours by inhibiting anaerobic decomposition. In essence, the chemicals create conditions which are unfavourable to the growth of bacteria or contain substances which are toxic to the bacteria. For example, calcium hydroxide (lime) or sodium hydroxide may be added to sewage to raise the pH beyond the range in which bacteria normally grow. Commercially available odour control chemicals for chemical toilets usually include either formaldehyde or zinc sulphate as a bactericide along with an odour masking compound.

The main disadvantage of using odour control chemicals is their cost and the effects they may have on subsequent treatment processes. When proper dilution is not provided and the chemically treated waste enters a subsequent sewage treatment plant in "slugs", biological treatment systems can be upset because of the toxicity of these odour control chemicals. This could result in several days of malfunction and poor quality effluent. In situations where this potential exists, the holding tank contents containing the odour control chemicals should be bled into the plant at a controlled rate.

The question of using odour control chemicals in conjunction with shipboard holding tanks is currently under study by the Department of the Environment.

2.4.6 Venting

It is normal practice to vent holding tanks to avoid the build-up of gases and this should be a definite requirement for such tanks in vessels. The vent outlet should be located well above the ship deck so that any odours will be dispersed in the atmosphere. If this is not possible, all exhaust gases should be filtered through carbon or activated charcoal prior to emission. These filters will require replacement from time to time but this is not difficult since they are available in cannister form and easily installed.

The vent system would have to be checked periodically to ensure that it is not blocked. This condition is most likely to occur during cold weather with the formation of ice in the vent. As a safety precaution, the vent should be equipped with an anti-flash screen.

A potential danger exists when back pressure causes air to enter the tank through the vent when the tank is being pumped out. This can be avoided by maintaining a positive air pressure in the tank by a fan or air compressor which would be the case if the tank contents were aerated.

2.4.7 Tank Flushing

In order to facilitate cleaning of the tank and transfer system to the shore facility, flush water should be supplied to the tank at sufficient pressure. This will help to dislodge any solids in the tank and lines leading to the shore facility.

2.5 Recommended Sub-Systems

While all the systems previously described have some useful features in the treatment and storage of sewage, it is felt that a holding tank should be as simple as possible, automatic in operation and as maintenance free as possible, therefore requiring the minimum of such treatment features.

The purpose of the holding tank is to retain the sewage in the vessel for later discharge to a shore facility where, presumably, it will then receive efficient treatment in a municipal sewage treatment plant. This means that BOD levels, coliform count or suspended solids criteria for the effluent are not as important as would be the case with a unit discharging directly overboard. The criteria for a holding tank, apart from the capacity, should be the comfort and safety of the crew and shore personnel (comfort being in the sense of freedom from odours or hazard), ease of pumping, reliability and simplicity in maintenance.

A simple tank and piping system of airtight construction should present no smell or danger, provided an efficient exhaust vent is led to atmosphere in a location where the exhaust will be dissipated harmlessly.

The problem, however, is that there could be a leak, especially in the piping or vent, caused by damage in a collision, by shock or vibration, or by corrosion due to acidity.

In addition, the question of spillage when hooking up to the shore facility cannot be overlooked, with its possible danger to the health of the crew and shore personnel and the hazard of the release of explosive fumes. Even the wind can be a factor to be reckoned with as a strong wind in the wrong direction can cause the exhaust from the tank to be blown into the accommodation or can cause a back pressure on the vent preventing the escape of the gases.

The problems of tank cleaning and maintenance are also to be reckoned with as the nature of the tank contents is such that it can be difficult to ensure regular maintenance. This again suggests as simple a system as possible to reduce maintenance, and a tank flushing system which will be automatic in operation.

Therefore, for vessels on which sewage would be held more than two days, specific steps must be taken to minimize these potential problems and this may best be achieved by equipping the tank with a comminutor at the influent end and providing aeration. For holding tanks that will be pumped out more frequently than once every two days, only a comminutor and a pump would be required. All tanks, regardless of pumpout frequency should be airtight, be vented to the atmosphere, and have the necessary water connections for flushing the tank and discharge line to the shore facility.

Where the tanks are fitted in conjunction with a sewage treatment device, however, whether flow-through or recirculating type, it is assumed that the sewage discharged to the holding tank has already been comminuted and treated by aeration or chemical dosing so that no subsystems are required on the holding tank. In the case where a holding tank is used as a surge tank before the flow-through device, the tank is usually supplied by the treatment tank manufacturer, and is considered outside the scope of this study. In any event, its capacity would not count in the holding capacity and a separate holding tank would still be required. Similarly, some flow-through system suppliers recommend a sludge tank with their system and here again this type of tank is considered to be outside the scope of this study.

3 DETAILED DESIGN OF HOLDING TANK SYSTEMS

3.1 Selection

To cover every type of tank and ship configuration would be beyond the scope of this study and, therefore, a range of typical tank sizes in two groups from 100 to 900 gallons capacity and from 1000 to 10,000 gallons capacity has been selected. The tanks will all be of the same shape but scantlings will be considered for a pressure head of 20 feet for the smaller vessels and 40 feet for the larger vessels, these being assumed to be the maximum in each case.

The largest tank is assumed to be 10,000 gallons and where it is found that gallonage in excess of this figure is required, then two tanks of smaller capacity should be fitted. This will usually assist in the space problem, since it is often easier to accommodate two smaller tanks than one large one. At the other end of the scale, tanks smaller than 100 gallons can be bought commercially as standard tanks without sub-systems.

For each typical ship of the classes given in Section 2.2 a tank from the standard range has been selected according to the water usage system under consideration and fitted with the sub-systems in accordance with Section 2.3.

This should cover most of the spectrum for ships sailing the Great Lakes and result in a sufficient range of holding tank systems to reasonably assess the economic impact and design considerations for any vessel.

3.2 Configuration

The configuration of holding tanks is one aspect which cannot be tied down to hard and fast rules due to the space problem which, in many cases, will mean that the shape of the tank will be of irregular form.

The following guidelines should be followed, however, for all tanks:

a) The tank should be separate from the hull structure.

b) The tank should be shaped at the bottom to allow the clean discharge of the solid content.

c) The tank should have all stiffeners on the outside to facilitate cleaning of the inside.

As previously stated the shape of the tank must suit the available space, but for the purposes of these guidelines a suitable form has been selected which has been used for all the tanks considered in order to obtain a true comparison. The configuration chosen is shown in Figure 2.

The tank configuration selected is higher than it is wide to give a good hopper shape at the bottom and because reducing the width reduces the free surface effect on GM. The hopper shape is offset as this is more economical than a symmetrical hopper and easier to construct. The tank is rectangular rather than circular, again because of the hopper shape but also because the flat surface is better for fitting manholes, pads, etc. At least one watertight and airtight bolted platetype manhole should be fitted for inspection purposes. Normally, it is preferred that this be on the top of the tank so that it can be opened even if the tank is full but if there is insufficient headroom then it can be located on the side. The discharge connection should be above the bottom of the tank so that it will not become blocked.

3.3 Capacity

3.3.1 Flow rates

The flow rate, expressed in gallons per man per day, varies with the type of water usage or associated treatment system fitted, whether or not passengers are carried, and also whether or not the grey water is included. The flow rates used in these guidelines were based on the following:

a) Flow rate - conventional water usage system.
This figure is taken at 30 gallons per man per day on the basis of 6 flushes of 5 gallons each per each man, per 24 hour day. This ignores the use of urinals which are flushed with much less water but it is not possible to estimate the ratio between urinal and water closet flushes especially on passenger vessels where children and women are on board. It is also assumed that this figure is the total of flush

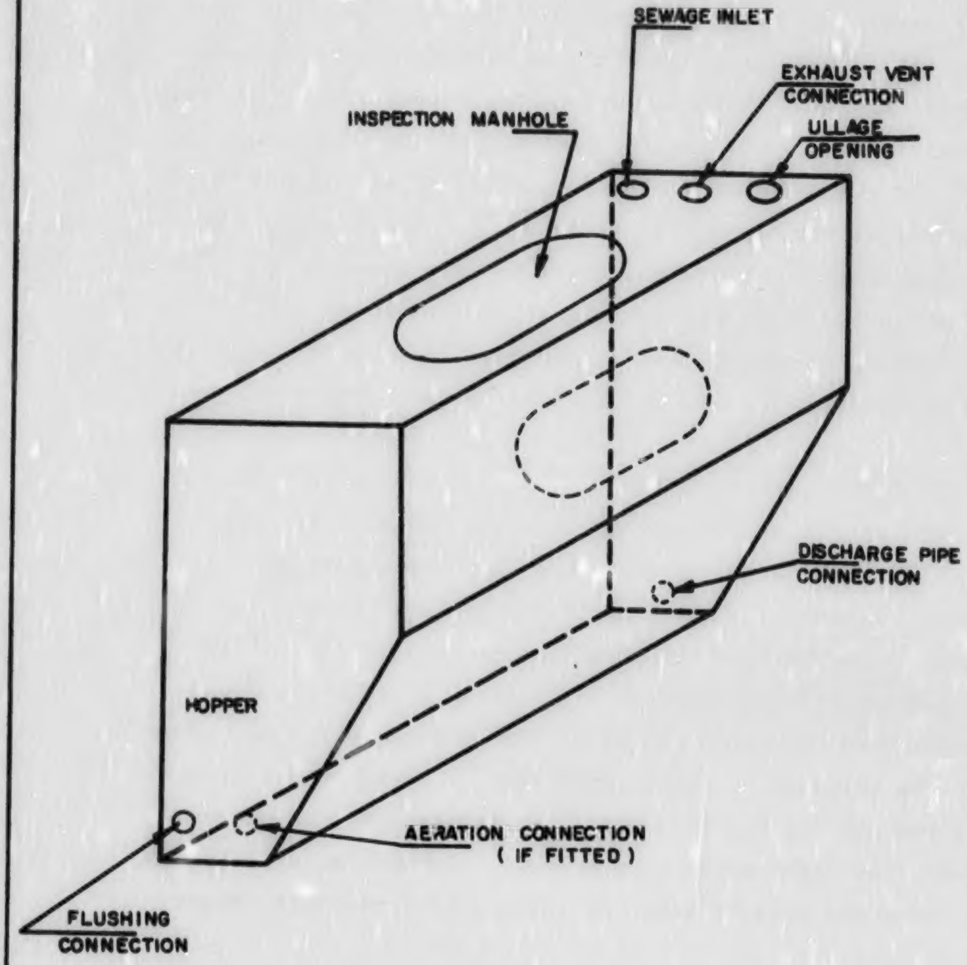

SEWAGE INLET
EXHAUST VENT CONNECTION
INSPECTION MANHOLE
ULLAGE OPENING
DISCHARGE PIPE CONNECTION
HOPPER
AERATION CONNECTION (IF FITTED)
FLUSHING CONNECTION

FIG. 2 TANK CONFIGURATION

water and body waste as the body waste amounts to only 0.4 gallons per man per day. The selected figure of 30 gallons per man per day should be regarded as a minimum flow rate for calculating tank capacities unless the ship's owner is prepared to prove the existence of a lower waste generation rate in his vessel, by actual record taken on board the vessel under consideration or by records from similar ships.

b) Flow rate - low water usage system.
This figure can vary, depending on whether the lower flow rate is achieved by vacuum system or by controlled flow flush valves fitted to the water closet and urinal fixtures.
With the use of a controlled flow flush valve the flushing water is reduced by limiting the time of the flush and as the timing can be adjusted, the flow rate can be varied. Probably a good average setting would give about 50% reduction from normal flow rates resulting, on the basis of six flushes per day, in a figure of 15 gallons per man per day.
On the other hand, a vacuum system will use about 0.33 gallons per flush and in this case the actual body waste figure must be added as it becomes of more importance. The total then is approximately 0.4 gallons per flush or again on our basis of six flushes per day, a total of say 2½ gallons per man per day. This gives a reduction of approximate reduction of 92% of the conventional flow volume. For the purposes of these guidelines a figure of 3 gallons per man per day has been used corresponding to the approximate flow with vacuum type systems. In all cases designated as low water usage systems in these guidelines this figure will apply.

c) Flow rate - with recirculating systems.
When a recirculating system is fitted, the treated liquid is recirculated and therefore it is only the excess fluid

which has to be contained in the holding tank. This excess will correspond to the flow of human waste which has already been given as 0.4 gallons per man per day. To provide storage for added chemicals and paper, 0.5 gallons per man per day is allowed. There will of course be times when all the recirculated fluid needs to be discharged either to clean it or to work on the system. On a laker with a crew of 35 this total would amount to about 600 gallons in addition to the normal flow rate. For the purposes of these guidelines it is recommended that the holding tank capacity should be sized on 0.5 gallons per man per day plus 400 gallons on the smaller ships and 0.5 gallons per man per day plus 600 gallons on the larger ships. The actual figures will have to be obtained from the manufacturer for the ship under consideration. Passenger ships and fishing vessels which are in port daily need not have this emergency capacity.

d) Flow rate - with flow-through sewage treatment systems. When fitted in association with a flow-through treatment unit, the holding tank capacity has been calculated to suit the same flow rates given in items (a) and (b), i.e., depending on whether a conventional or low water usage system is fitted.

e) Flow rate - passenger vessels. All the preceeding figures apply, as related to the type of water system in use, if both crew and passengers sleep or board the ship. The passenger ships considered, however, are ferries or tour vessels where the round trip voyage is about four hours maximum. This gives rise to a different situation and more reasonable basis for sizing the tanks would be on the following flow rates, applicable to registered passenger capacity of the ship and not the number of passengers carried on any particular trip.

1) Large Vessels.

Crew - Assume 24 hour day and flow rates as given previously.

i.e. 30 gallons per man per day - conventional water usage
3 gallons per man per day - low water usage
0.50 gallons per man per day - recirculating systems

Passengers - On a four hour voyage, and assuming two trips per day one flush per passenger per trip must be allowed. This gives the following:

i.e. 10 gallons per man per day- conventional water usage
1 gallon per man per day - low water usage
0.15 gallons per man per day - recirculating systems.

2) Small vessels (Water buses).

Crew - Assume 12 hour day and 50% of normal flow rates.

i.e. 15 gallons per man per day - conventional water usage
1.5 gallons per man per day - low water usage
0.25 gallons per man per day - recirculating systems

Passengers - In the water bus type of operation 25% should be the maximum for passengers using the toilet in one trip and it is doubtful if any ships of this type have toilet facilities to allow more. The average round trip voyage would be of two hours duration with six trips per day, thus the figures become

7.5 gallons per man per day - conventional water usage
0.75 gallons per man per day - low water usage

0.12 gallons per man per day -
recirculating systems.

f) Flow rate - grey water.

If the holding tanks are to contain grey water in addition to the sewage, then all the preceding flow rates for non-passenger ships will be increased by 30 gallons per man per day, as there are no vacuum type or low water systems applicable to the grey water. On the passenger ships the figures must be modified as follows, the rates again applying to the registered passenger capacity of the ship and not the number of passengers on any particular trip.

1) Large Vessels.

Crew - normal rate of 30 gallons per man per day.

Passengers - allowing for wash basins, galley and bar facilities (no showers or laundry) - 15 gallons per man per day.

2) Small Vessels (water buses).

Crew - 3 gallons per man per day wash basins only.

Passengers - 1½ gallons per day on the basis that only the 25% using the toilets use the washbasins on each trip.

Summary

Table 2 gives the foregoing flow rates in tabular form for ease of comparison. Figure 3 shows the basic flow rates which indicate the considerable reductions achieved by the vacuum and recirculating types of systems.

3.3.2 Retention period

The retention period for which the holding tanks should be designed is primarily based on the class and service of the vessel.

Where a vessel sails continuously out of one port and always returns to that port the retention time can suit the owner, provided he does not contravene the no discharge regulations, but where the voyage

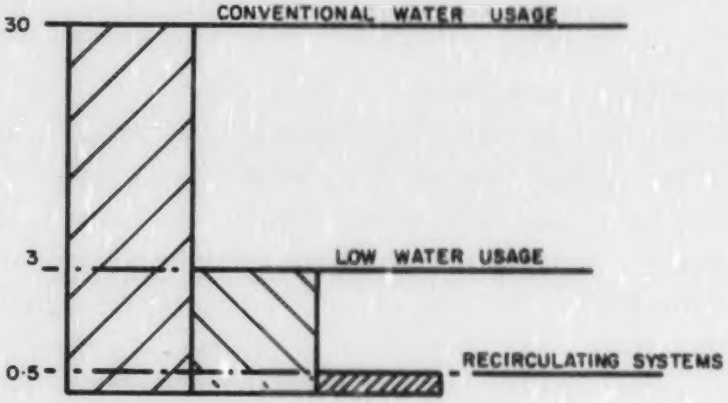


FIG. 3 BASIC FLOW RATES (GALLS / MAN / DAY)

SYSTEM	FLOW RATES (GALLS / MAN / DAY)	
	SEWAGE	GREY WATER
CONVENTIONAL WATER	30	30
LOW WATER	3	"
RECIRCULATING SYSTEMS	0·50	"
FLOW THROUGH (CONVENTIONAL)	30	"
FLOW THROUGH (LOW WATER)	3	"

TABLE 2A FLOW RATES NON- PASSENGER SHIPS

VESSEL		FLOW RATES (GALLS / MAN / DAY)			
		SEWAGE			GREY WATER
		CONVENTIONAL WATER	LOW WATER	RECIRC. WATER	
PASSENGER (LARGE)	CREW	30	3	0·50	30
	PASSENGERS	10	1	0·15	15
PASSENGER (WATER BUS)	CREW	15	1·5	0·25	3
	PASSENGERS	7·5	0·75	0·12	1·5

TABLE 2B FLOW RATES PASSENGER SHIPS

is ongoing to other ports, the time may have to suit the availability of shore facilities and not the owner. The time must in any case be at least that time it takes to travel between suitable shore facilities, or to an area in which discharge is permissible via a flow-through device, and the time in port must be added to both. A suitable shore facility is not necessarily the nearest one as it may be preferable to hold until the vessel is fuelling in order to save time and money. The size of tank of course can effect draft, trim, stability and deadweight as well as being governed by the space available in the vessel, so that the answer to the retention time problem will probably be a compromise solution based on all these factors, particularly in the smaller vessels.

For the purposes of this study the retention times for each group of vessels are based on the following. The times are given in tabular form in Table 3 for ease of comparison.

Lakers and Tankers

These vessels should not be guided so much by questions of draft, trim and stability or deadweight, but more by pumping out when fuelling and this means five to seven days holding between fuel stops. The time in port will be between 1 and 3½ days. Therefore, an average minimum holding time of five and two days has been assumed for a total of seven days, but as these vessels can quite frequently experience 100% time delays due to ice conditions, storms, seaway delays and longshoremen slow-down, the tank should be designed for 14 days holding.

Dredges (Large)

Dredges go out on contract, experience delays and can spend a long time in port between contracts. While out on long contracts, they are often serviced by a tug and barge unit which would have a holding tank to receive the sewage from the dredge. Therefore, 14 days holding is recommended for this class of vessel as well.

Passenger Vessels (Large)

The type of vessel included in these guidelines is making short trips. The longest time in port is between the last trip of the day and the first in the morning so these vessels could discharge every day if the owners wished. It must be assumed that the voyages may be entirely in

VESSEL	HOLDING TIME (DAYS)	MARGIN INCLUDED IN TIME(%)
LAKERS, TANKERS & DREDGES(LARGE)	14	100
PASSENGER VESSELS (LARGE)	1¼	25
PASSENGER VESSELS (WATER BUS)	1	100
TUGS	14	100
FISHING VESSELS & DREDGES(SMALL)	7	100

TABLE 3 HOLDING TIMES

"no discharge" zones so that the holding time would average about 8 hours sailing and 16 in port for a total of 24 hours, but the passengers would not be on board while in port. In the case of these vessels, there is little likelihood of excessive delays as a frequent occurrence. Therefore a reasonable margin would be 25% to give a total of 1¼ days holding. In any case, the number of passengers probably makes longer retention impracticable due to the high flow rate.

Passenger Vessels (Water Bus)

These vessels would be similar to the large passenger ships but the holding time would be 12 hours sailing and 12 hours in port with neither crew nor passengers on board while in port. One day holding should therefore be ample for this type of vessel, which actually gives 100% margin.

Fishing Vessels and Dredges (Small)

The fishing vessels on the Great Lakes are out less than a day and out daily when the fishing is good. It is recommended, however, that the tank be sized for seven days holding since the crew will probably not want to discharge more than once a week during the busy season. Small dredges are usually out less than one day and time in port can depend on the contracts they obtain. Seven days holding would be reasonable for this class of vessel.

Tugs

The tugs are vessels which can experience 100% delays in their voyages and, at the same time, they can have a long period in port between contracts. Time between fuel stops would average five to seven days and therefore the tanks should be sized on the basis of five and two for a minimum of seven days and a 100% delay, giving a total of 14 days holding time.

3.3.3 Capacities

Tank capacities are based on the product of flow rate, holding time and number of people, and are expressed in gallons.

To calculate the capacity the following formula should be used:

$$Q = N \times T \times R$$

where Q = Capacity in gallons
N = Number of crew
T = Retention time in days
R = Flow rate in gallons per man per day

For passenger vessels, the formula will need to be calculated for crew and passengers separately and the tank capacity (Q) will be the sum of the two figures.

For the vessels under consideration the capacities are given in the tables inserted in Figures 5 to 12 in Section 3.4. As a guide for sizing tanks in general, graphical solutions are depicted in Figure 4. The minimum required capacities given in the tables inserted are those obtained using the above formula and the tank sizes are selected from the tanks shown in Section 3.5, Figures 13 and 14. Tank capacities indicated are for sewage only.

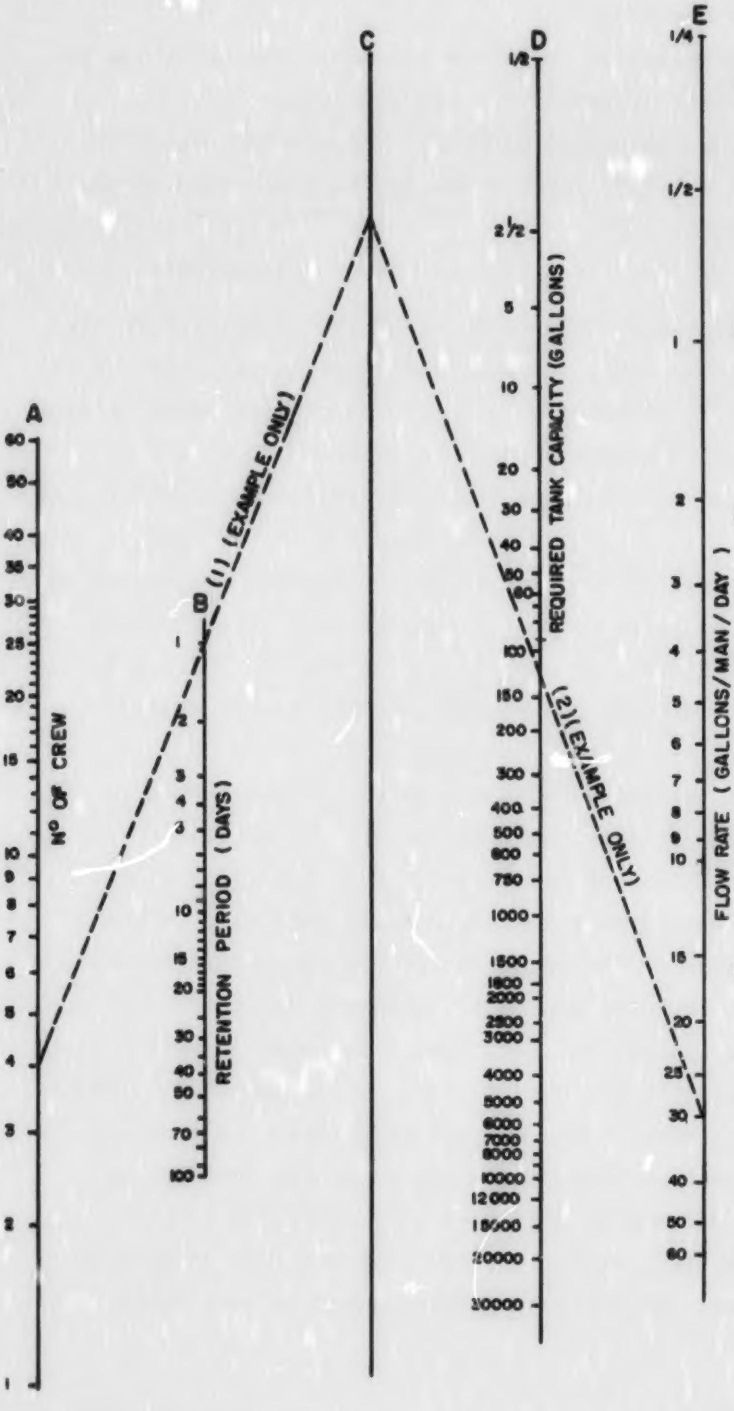
The man/day capacities for passenger vessels marked * are based on the number of crew only, as passengers are taken at a reduced flow rate. The capacities marked † and † include the 600 gallons and 400 gallons, respectively, for emergency, as described in Section 3.3.1.

All the capacities indicated are based on sewage only and should be increased, or additional tanks used, if grey water is to be retained. The tanks for grey water would be calculated as for sewage but using the grey water flow rates given in Section 3.3.1.

As previously stated in Section 3.1, 10,000 Imp. gallons is the largest tank size recommended; where gallonage in excess of this figure is required then two smaller tanks should be used.

3.4 Location

Holding tanks will, in general, be fitted below the accommodation where it can best be served by a gravity feed system of sanitary piping. An exception of course is where the tank is used in association with a vacuum type system which is not dependent on gravity feed and, therefore, is subject to less restriction on location.



INSTRUCTIONS

1- DRAW STRAIGHT LINE CONNECTING Nº OF CREW ON SCALE A WITH RETENTION PERIOD (INCLUDING MARGIN) ON SCALE B AND CONTINUE LINE UNTIL IT INTERSECTS THE C SCALE AS SHOWN BY LINE (1) IN EXAMPLE.

2- DRAW SECOND LINE CONNECTING THE POINT OF INTERSECTION ON THE C SCALE WITH THE FLOW RATE ON THE E SCALE AS SHOWN BY LINE (2) IN EXAMPLE.

3- READ THE REQUIRED TANK CAPACITY WHERE THE SECOND LINE INTERSECTS THE D SCALE (120 GALLONS IN EXAMPLE)

4- WHERE PASSENGERS ARE CARRIED THE PROCEDURE CAN BE REPEATED USING THE A SCALE AS Nº OF PASSENGERS ÷ 10 AND READING CAPACITY ON D SCALE AS GALLONS ÷ 10 TANK CAPACITY WILL BE TOTAL OF CREW AND PASSENGER READINGS FROM SCALE D.

5- IF GREY WATER IS TO BE HELD THE SAME PROCEDURE CAN BE FOLLOWED USING THE COMBINED FLOW RATE FOR SEWAGE AND GREY WATER I.E. USE 60 GALLONS/ MAN/ DAY. FOR CONVENTIONAL WATER USAGE.

FIG. 4 HOLDING TANK CAPACITY NOMOGRAPH

The tanks can usually be located as follows:

a) Below the accomodation.
b) As high as possible to reduce pressure head but below the lowest toilet or urinal for gravity feed.
c) In a space such as the machinery space where engineers would normally have access during the performace of their daily duties.
d) Low in the ship to suit the stability requirements.

Where the tank cannot be located below the lowest toilet with conventional water usage systems, a sewage lift station will need to be fitted. This will be a small holding tank for about eight hours holding and a pump which will be automatic in operation, actuated by a float switch to transfer to the main holding tank. A similar arrangement will be necessary in the case of a Laker with forward and aft accommodation. In this case, the lift station would be below the forward accommodation and a comminutor would be included on the pump suction side in order to reduce the diameter of the long run of pipe to the aft holding tank. The capacities of such tanks are not included in the required holding tank capacity.

As previously mentioned, when a holding tank is fitted in conjunction with a vacuum system, the tank can be located almost anywhere convenient, which is one advantage of this type of system.

Figures 5 to 12 indicate the recommended locations in the selected classes of vessels. The locations are in the machinery space in each case, where the engineer can easily maintain and operate it. Although many machinery spaces are very tight for space, in most cases a tank can be accommodated by building a platform off the shell plating or other suitable arrangement. The tank can be arranged so that all points of inspection, such as pumps etc., can be at the front or at one end so that only a minimum of 3'0" clearance along the front or one end would be required, with the other side and end having only minimum normal clearances of inches to provide acess to seat bolts.

TYPICAL TANK SIZES	CONVENTIONAL WATER	LOW WATER	RECIRC. WATER
MINIMUM CAPACITY (GAL)	12,600	1260	810 †
RECOMMENDED CAPACITY (GAL)	15,000	2000	900
APPROX. DIMENSIONS L X W X H	2 TANKS 15' X 9' X 10'	12' X 5' X 6'	8' X 4' X 5'

BASED ON 14 DAYS RETENTION

30 CREW

420 MAN-DAYS CAPACITY

† INCLUDES 600 GALLONS EMERGENCY

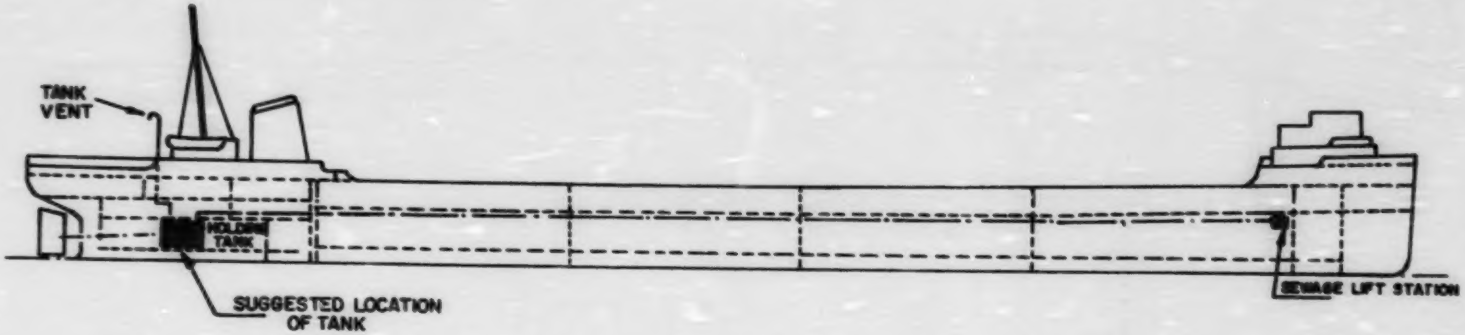

TANK VENT
HOLDING TANK
SUGGESTED LOCATION OF TANK
SEWAGE LIFT STATION

FIG. 5 LAKER

TYPICAL TANK SIZES

	CONVENTIONAL WATER	LOW WATER	RECIRC. WATER
MINIMUM CAPACITY (GAL)	12,600	1260	810+
RECOMMENDED CAPACITY (GAL)	15,000	2000	900
APPROX. DIMENSIONS L X W. X H	2 TANKS 15'X9'X10'	12'X5'X6'	8'X4'X5'

BASED ON 14 DAYS RETENTION

30 CREW

420 MAN-DAYS CAPACITY

+ INCLUDES 600 GALLONS EMERGENCY

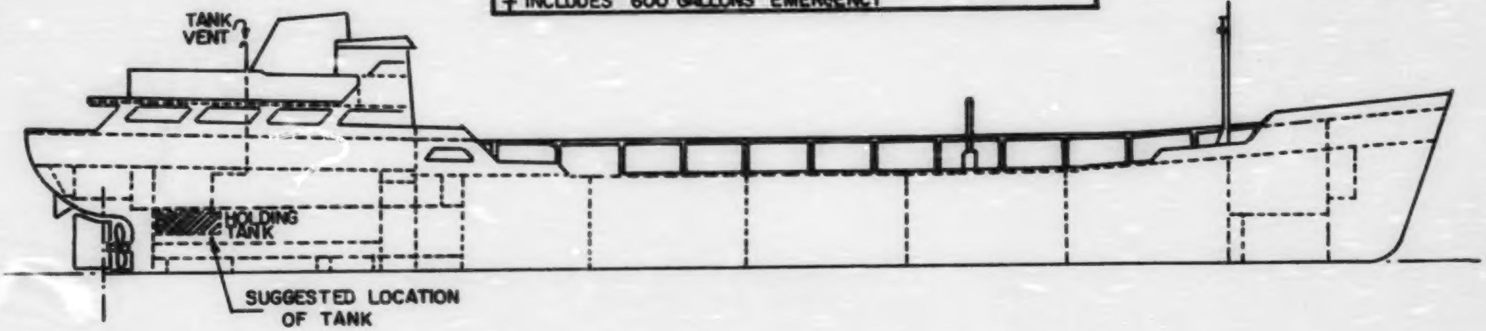

TANK VENT
HOLDING TANK
SUGGESTED LOCATION OF TANK

FIG. 6 TANKER

TYPICAL TANK SIZES

	CONVENTIONAL WATER	LOW WATER	RECIRC. WATER
MINIMUM CAPACITY (GAL)	12,600	1260	810 †
RECOMMENDED CAPACITY (GAL)	15,000	2000	900
APPROX. DIMENSIONS L X W X L	2 TANKS 15'X 9'X 10'	12'X 5'X 6'	8'X 4'X 5'

BASED ON 14 DAYS RETENTION
30 CREW
420 MAN-DAYS CAPACITY

† INCLUDES 600 GALLONS EMERGENCY

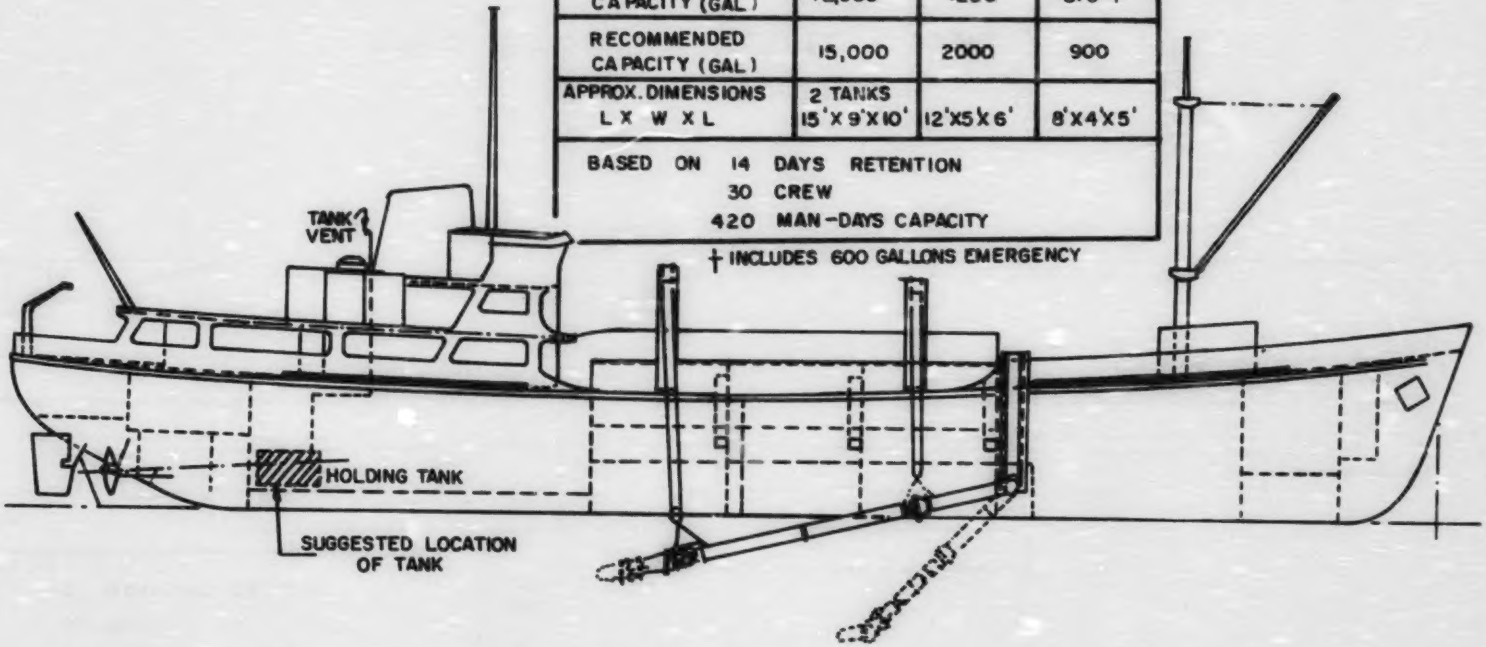

TANK VENT
HOLDING TANK
SUGGESTED LOCATION OF TANK

FIG. 7 DREDGE (LARGE)

TYPICAL TANK SIZES

	CONVENTIONAL WATER	LOW WATER	RECIRC. WATER
MINIMUM CAPACITY (GAL)	7250	725	112
RECOMMENDED CAPACITY (GAL)	7500	900	200
APPROX. DIMENSIONS L X W X H	15'X9'X10'	8'X4'X5'	6'X2'X3'

BASED ON 1¼ DAYS RETENTION
60 CREW
75* MAN-DAYS CAPACITY
* (CREW ONLY)

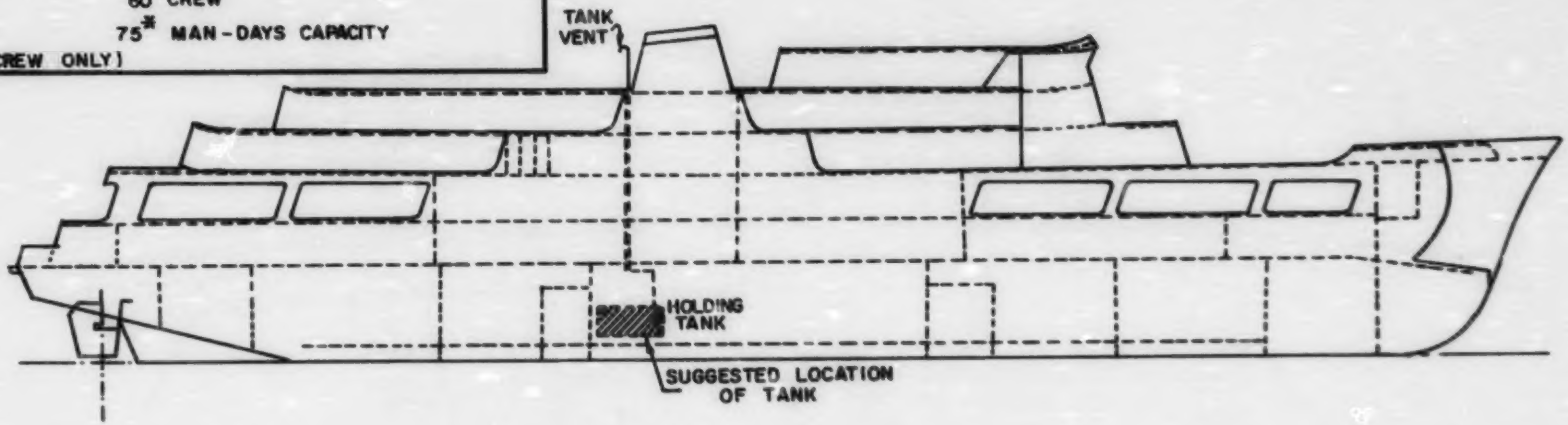
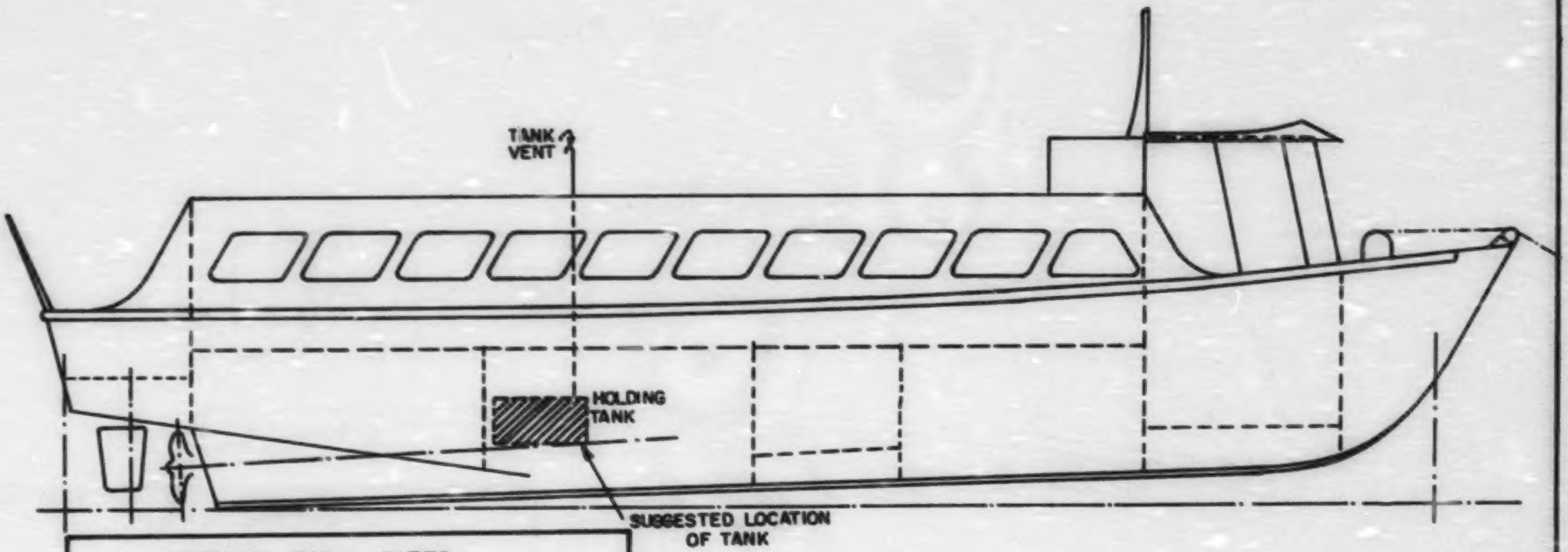

TANK VENT
HOLDING TANK
SUGGESTED LOCATION OF TANK

FIG 8 PASSENGER VESSEL (LARGE)


TANK VENT
HOLDING TANK
SUGGESTED LOCATION OF TANK

TYPICAL TANK SIZES

	CONVENTIONAL WATER	LOW WATER	RECIRC. WATER
MINIMUM CAPACITY (GAL)	810	81	13
RECOMMENDED CAPACITY (GAL)	900	100	15
APPROX. DIMENSIONS L X W X H	8' x 4½' x 5'	3' x 2½' x 3'	3' x 1' x 1'

BASED ON 1 DAYS RETENTION
4 CREW
* (CREW ONLY) 4* MAN - DAYS CAPACITY

FIG. 9 PASSENGER VESSEL (WATER BUS)

TYPICAL TANK SIZES

	CONVENTIONAL WATER	LOW WATER	RECIRC. WATER
MINIMUM CAPACITY (GAL.)	420	42	7
RECOMMENDED CAPACITY (GAL.)	500	50	10
APPROX. DIMENSIONS L X W. X H	7'x 3'x 4'	4'x 2'x 1'	2'x 1'x 1'

BASED ON 7 DAYS RETENTION
2 CREW
14 MAN-DAYS CAPACITY

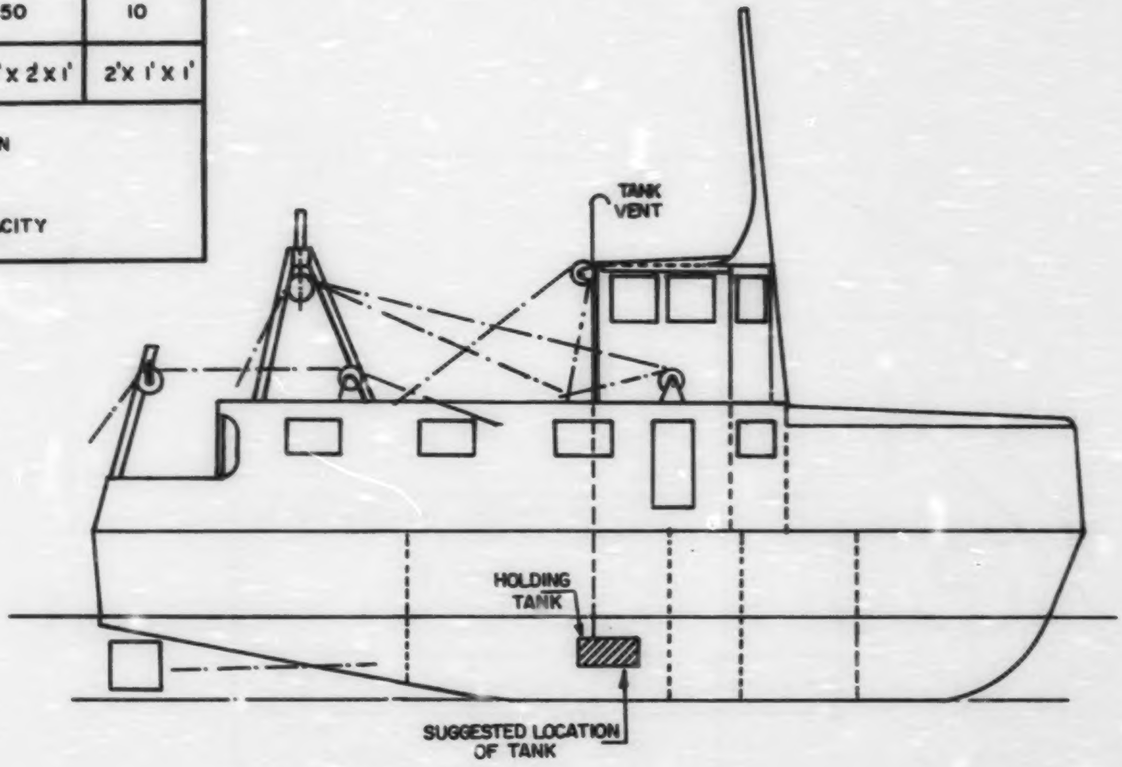

TANK VENT
HOLDING TANK
SUGGESTED LOCATION OF TANK

FIG. 11 FISHING VESSEL

TYPICAL TANK SIZES

	CONVENTIONAL WATER	LOW WATER	RECIRC. WATER
MINIMUM CAPACITY (GAL)	420	42	407 ǂ
RECOMMENDED CAPACITY (GAL)	500	50	500
APPROX. DIMENSIONS L X W X H	7' x 3' x 4'	4' x 2' x 1'	7' x 3' x 4'

BASED ON 7 DAYS RETENTION
2 CREW
14 MAN-DAYS CAPACITY

ǂ INCLUDES 400 GALLONS EMERGENCY

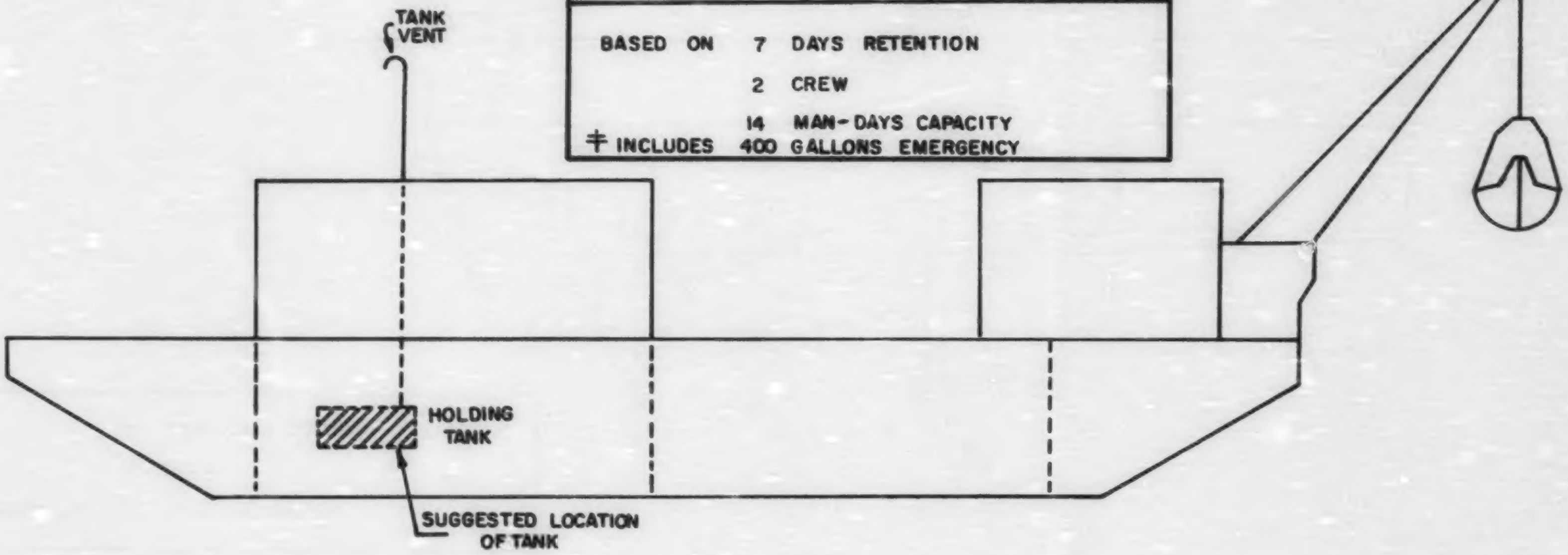

TANK VENT
HOLDING TANK
SUGGESTED LOCATION OF TANK

FIG. 12 DREDGE (SMALL)

3.5 Structure

The structural details given herein are for tanks of steel construction only, since this is the most likely material to be used by a shipyard. The steel should be mild steel of shipbuilding quality. Aluminum tanks would give a reduction in weight but would also increase the cost and complicate installation because of dissimilar metal corrosion problems. In view of the fact that the greatest weight involved is the weight of the liquid, the weight saving would not warrant the higher cost.

Stainless steel tanks would not save weight but would, of course, give better resistance to corrosion, again at higher cost. Welding of such a tank would require more care in the selection of electrodes and welding procedures than a mild tank. Again, the use of stainless steel is not warranted at the cost involved.

Copper alloy tanks would be in the same category as the stainless steel and have not been considered further.

Rigid rubber tanks on a one off basis would not be feasible because they would be uneconomical to produce. In the small sizes up to 33 Imp. gallons capacity they are commercially available and are used, in pleasure boats mainly, with some success. Their flexibility and light weight makes installation easy although they are usually supported by the piping, which is not recommended. Standard flexible rubber tanks are also available up to 210,000 gallons capacity but are not considered suitable for this purpose.

Fibreglass tanks are a reasonable alternative to the steel as far as cost but only if produced in quantity by cutting pre-fabricated panels. The number of variables involved in the tank configuration precludes making a mold for the tanks for economical reasons, which means laying up all sides, top and bottom by hand as standard panels, cutting to size, taping, and laying up the corners. Pipe connections and seating lugs would need to be inserted during the laying up process and this means that a number of the pre-fabricated panels would require standard connections inserted. This would mean that probably only a limited standard range would be produced and, therefore, this material has not been considered further.

The steel structure has been designed in accordance with the following information and drawings, Figures 13 and 14.

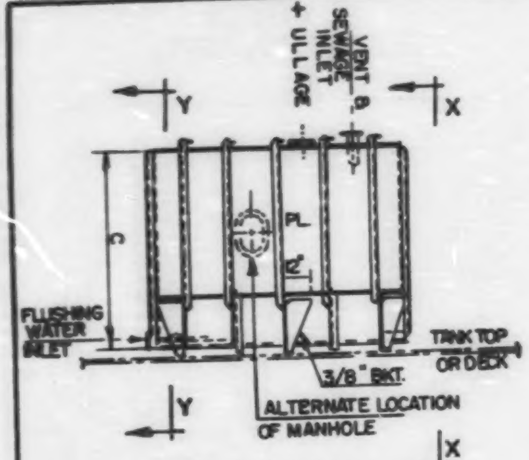
1) Plating is not less than 1/4" thick to allow for corrosion.
2) Plating and stiffeners are to be sized to Classification Society rules for deep tanks using pressure head to height of the lowest toilet served. The tanks drawn herein have been sized to suit a head of 20 feet for the smaller ships and 40 feet for the larger ships, these being considered the maximum in each case.
3) Stiffeners are on the outside.
4) Although welding is not indicated on the drawings, it is preferable to have as little as possible and the tank should have flanged or radiused corners to cut out welded joints at the corners. Welded seams are often the starting point for corrosion problems and can harbour bacteria. Welds on the inside of the tank should be ground smooth.
5) A bracket structure has been incorporated under the tank bottom which would be bolted to an angle seating or similar arrangement. The tank must not be supported by the piping.
6) The necessary pipe connections and inspection man hole are indicated on the drawings and each drawing includes a table giving capacities, dimensions, scantlings and weights.

3.6 Effect on Stability

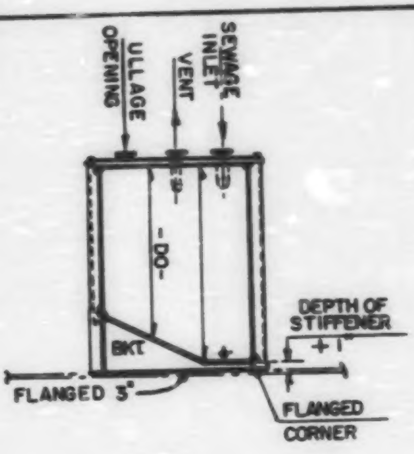
It is impossible to predict precise effects on stability without the particulars of the vessel under consideration and the details of the actual holding tank.

As a guide, however, particulars for the classes of vessels under study have been assumed and the sizes and capacities of tanks obtained from Section 3.3 have been used.

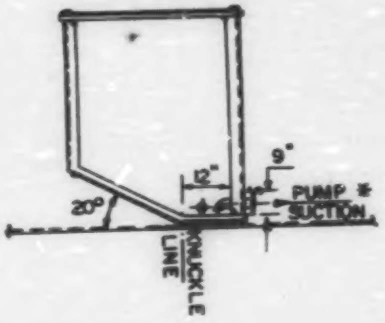
The changes in GM due to the fitting of the tanks in the locations indicated in Figures 5 to 12 have been estimated. The results for conventional water systems and low water systems, respectively, are negligible for larger vessels, and even on the smaller vessels the largest adverse effect is with conventional water, and gives a reduction in GM of less than 4%. The changes for the low water systems are even smaller and with


VENT B
SEWAGE INLET
+ ULLAGE
Y
X
C
PL.
12"
FLUSHING WATER INLET
TANK TOP OR DECK
3/8" BKT.
ALTERNATE LOCATION OF MANHOLE
Y
X

SIDE ELEVATION


SEWAGE INLET
VENT
ULLAGE OPENING
-DO-
BKT.
DEPTH OF STIFFENER
+1"
FLANGED 3"
FLANGED CORNER

SECTION X-X


9"
12"
20°
PUMP * SUCTION
KNUCKLE LINE

SECTION Y-Y

FIG. 13

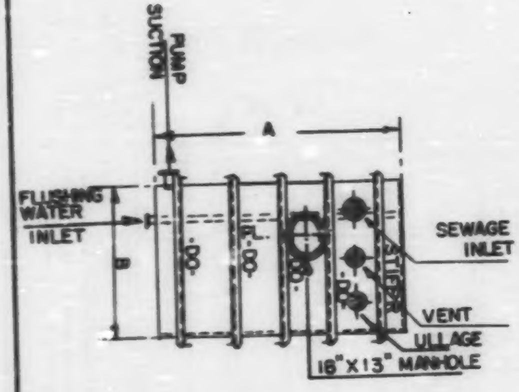
TYPICAL CONSTRUCTION DETAIL

OF

HOLDING TANK

100 TO 900 GALLONS

* INTERNAL SUCTION PIPE OPENING
TO BE 1/2" CLEAR FROM TANK BOTTOM


PUMP SUCTION
A
FLUSHING WATER INLET
B
-DO-
PL.
-DO-
DO
STIFFR
SEWAGE INLET
VENT
ULLAGE
16"X13" MANHOLE

PLAN VIEW AT TOP OF TANK

CAP.Y (GALLS)	SIZE (FT.)			HEAD (h) = 20 FT.					HEAD (h) = 40 FT				
				DRY WEIGHT	WET WEIGHT (L/T)		SCANTLING		DRY WEIGHT	WET WEIGHT (L/T)		SCANTLING	
	A	B	C	(L/T)	50%	90%	PL.	STIFFENER 24" SP.	(L/T)	50%	90%	PL.	STIFFENER 24" SP.
100	3	2	3	0·29	0·52	0·70	5/16"	3" X 5/16" F.B.	0·31	0·54	0·72	5/16"	4" X 5/16" F.B.
200	6	2	3	0·50	0·96	1·33			0·54	1·00	1·37		
300	5	3	4	0·62	1·31	1·80		3" X 3/8" F.B.	0·67	1·36	1·85		3" X 2½" X 5/16" L
400	6	3	4	0·73	1·65	2·38			0·76	1·68	2·41		
500	7	3	4	0·81	1·96	2·87			0·84	1·99	2·90		
700	7	4	5	1·08	2·70	4·00		3" X 2½" X 5/16" L	1·18	2·80	4·10		3½" X 3" X 3/8" L
900	8	4	5	1·29	3·37	5·03			1·37	3·45	5·11		

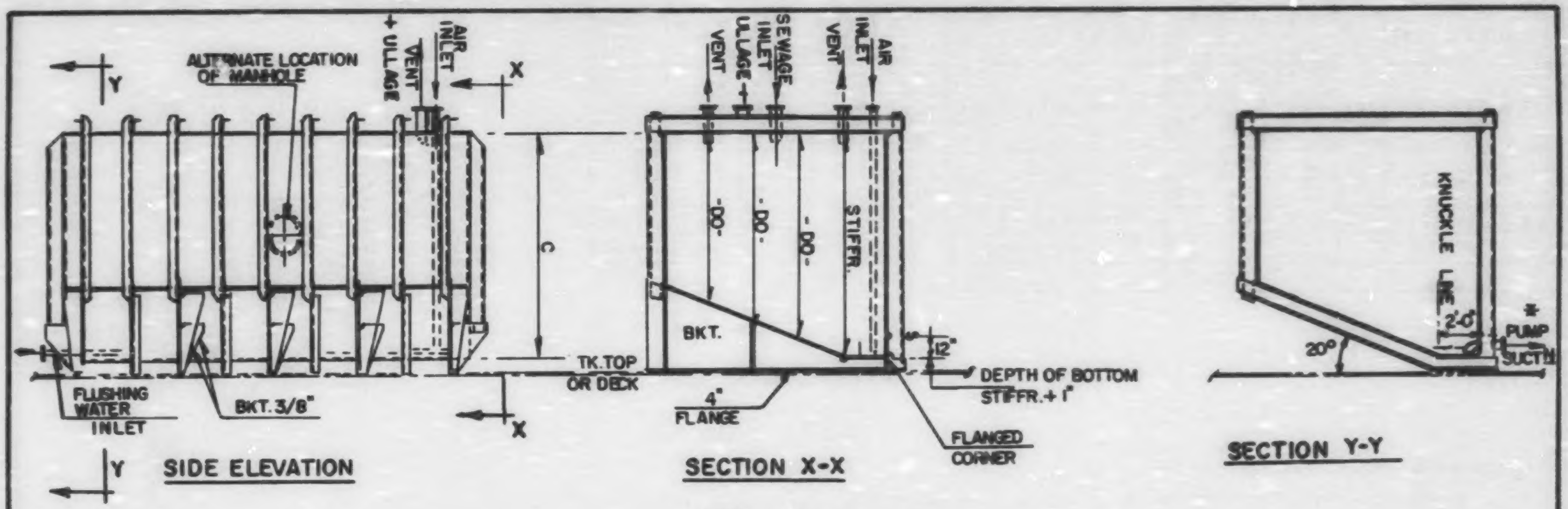

ALTERNATE LOCATION OF MANHOLE
AIR INLET
VENT + ULLAGE
X
Y
C
TK. TOP OR DECK
FLUSHING WATER INLET
BKT. 3/8"
SIDE ELEVATION
VENT
ULLAGE
SEWAGE INLET
AIR INLET
STIFFR.
-DO-
BKT.
4" FLANGE
12"
DEPTH OF BOTTOM STIFFR. + 1"
FLANGED CORNER
SECTION X-X
KNUCKLE LINE
2'-0"
20°
* PUMP SUCTN
SECTION Y-Y

FIG. 14

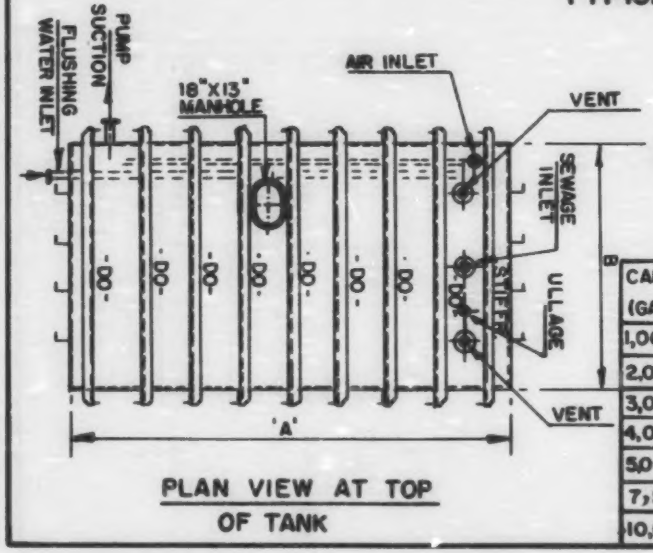
TYPICAL CONSTRUCTION DETAIL

OF

HOLDING TANK

1,000 TO 10,000 GALLONS

* INTERNAL SUCTION PIPE OPENING
TO BE 1/2" CLEAR FROM TANK BOTTOM


PUMP SUCTION
FLUSHING WATER INLET
18"X13" MANHOLE
AIR INLET
VENT
SEWAGE INLET
ULLAGE
VENT
STIFFR.
-DO-
'A'
B
PLAN VIEW AT TOP OF TANK

CAP.Y	SIZE (FT.)			HEAD (H) = 20 FT.					HEAD (H) = 40 FT.				
				DRY WEIGHT	WET WEIGHT (L/T)		SCANTLING		DRY WEIGHT	WET WEIGHT (L/T)		SCANTLING	
(GALLS)	A	B	C	(L/T.)	50%	90%	PL.	STIFFENER 24" SP.	(L/T.)	50%	90%	PL.	STIFFENER 24" SP.
1,000	9	4	5	1·35	3·66	5·50	5/16"	3"x2 1/2"x5/16" L	1·66	3·97	5·81	3/8"	3 1/2x3"x 3/8" L
2,000	12	5	6	2·27	6·88	10·6		3"x2 1/2" x3/8" L	2·79	7·40	11·1		4"x3 1/2 x 3/8" L
3,000	13	6	7	2·99	9·91	15·5		3 1/2" x 3" x 3/8" L	3·64	10·6	16·1		5"x3 1/2 x3/8" L
4,000	13	7	8	3·56	12·8	20·2		4" x3 1/2 x 3/8" L	4·32	13·6	20·9		6"x3 1/2" x3/8" L
5,000	16	7	8	4·38	13·6	21·0			5·33	14·6	21·9		
7,500	15	9	10	5·86	23·2	37·0		5"x3 1/2" x 7/16" L	7·21	24·5	38·4		6"x4" x1/2" L
10,000	19	9	10	7·59	30·7	49·1			9·38	32·5	50·9		

the recirculating system being smaller again, further calculatins have not been made.

In view of the fact that the selected tanks are probably the maximum size that would be fitted in each case, the only way the effect on stability could increase is if the tanks are fitted at a higher level in the vessels. It is not likely, however, that the tanks could be fitted much higher and, therefore, any change would be minimal.

With the tanks as indicated, the free surface effect should not be a problem and internal baffles may be omitted from the tanks although the effect on stability should always be checked.

3.7 Protective Coatings

The steel tank should be coated inside to protect against corrosion and the preferred coating is coal tar epoxy. Vinyl or vinylidene chloride coating schemes are also suitable as far as resistance to acids and chemicals are concerned, but they require more coats to obtain a suitable build-up and are more prone to fracture during tank cleaning if at anytime a brush or other cleansing tool is used.

The coal tar epoxy can be applied to the bare steel but the steel must be blast cleaned to SSPC-SPIO specification. From a protection point of view, it is better to do this after welding is complete but if the plates are shop blasted, then a good pre-weld primer must be applied immediately and the coal tar epoxy applied on top at a later date.

The coal tar epoxy must not be applied at temperatures below 40°F (5°C) and two costs should be applied to a total dry film thickness of 12 mils minimum.

At least seven days must be allowed for the coating to fully cure and the tank cannot be used in this period.

Provided the protective coating is properly applied to a surface which has been blasted clean correctly, the coating should give at least five years minimum protection to the steel. Any damaged area which may arise due to unforseen mechanical action would need re-blasting and touching up with two touch up coats.

All coating schemes and surface preparation should be carried out in accordance with the paint manufacturers' recommendations.

3.8 Piping and Pumping Detail

3.8.1 Pumps

The discharge pumps are the most important components of the holding tank system and, therefore, it is recommended that two discharge pumps be fitted, one working and one stand-by. Each pump should be capable of discharging the maximum contents of the holding tanks in less than 30 minutes. The pumps should be piped such that they can discharge the tank contents to a shore station or overboard in an emergency. Discharge pressure for each pump should be sufficient to pump from the lowest point in the tank to the discharge station plus 30 ft head. The pumps should be of non-clog type, capable of handling heavy liquids and suspended solids up to 2" in dimension. These criteria would normally not be required but in case of failure of the comminutor, and use of the manual by-pass, solids may need to be pumped without having gone through the comminution process. For this duty, centrifugal type pumps with non-clog impellers are preferred, although other types may be acceptable provided they conform to the foregoing pumping criteria. The pump suction should be located at or below the level of the suction connection of the tank.

Pump materials should be compatible with the liquid pumped and it is considered that all stainless steel pumps are the most suitable for this service, as stainless steel is the least susceptible to the abrasive action of the liquid and can best withstand the corrosive components in the wastes handled. Alternatively, a high strength cast iron casing with stainless steel shaft and impeller would be acceptable.

3.8.2 Piping

Piping in general should be laid out in an efficient manner with good grading down to the holding tank(s), in the case of a gravity system, for proper drainage and to prevent pockets where sludge may accumulate creating a blockage.

A generously sized p-trap should be installed just upstream of the tank to prevent odours from the holding tank backing up into the accommodation. All waste drainage piping between washrooms and the holding tank should be of an approved type polyvinyl chloride (PVC) material.

Piping from the tank(s) to the pumps, and from the pumps to the shore station and overboard, should be schedule 40 steel, heavy galvanized after fabrication. As shown in Section 3.11, this part of the system will be flushed through after discharge. Air supply piping, fitted on those tanks where forced ventilation of the tanks is used, may be of PVC material.

Each system is shown diagrammatically in Figures 15 and 16 for a small tank system without aeration and for a large tank system including comminution and aeration, respectively.

Where a comminutor is used, it is recommended that a manual by-pass be fitted for use when the comminutor is out of order.

A generously sized vent pipe of PVC material should be installed as indicated on the diagrams. Generally, the vent pipe should be the same size as the supply pipe in a gravity system but should not be smaller than 4" nominal diameter. On a large tank, two vent connections may be required.

The vent pipe should be terminated well clear of the highest deck house and fitted with an anti-flash screen at the outlet opening.

3.8.3 Flushing tank and system

Flushing water in most cases will be available from the ship's sanitary system. Where no sanitary water system is fitted or where sufficient pressure is not available in this system, either a separate pump should be provided for flushing duty or a branch may be provided from the ship's fire system at suitable pressure. The required pressure for efficient operation of the water jets inside the tank would be 30 psi minimum and should not exceed 100 psi. The amount of water used for flushing during the 60 second cleaning cycle as described in Section 3.11 depends on the number of jets in the tank and pressure in the system. The volume of water used will be from 12 GPM to 60 GPM minimum depending on the length of the tank and number of jets. Each jet will supply 215 GPM at 100 ft head pressure. Water should be sprayed on the tank surface for flushing through 1/8" diameter holes drilled in a two inch diameter pipe at 9" intervals. This flushing water header should be fitted in the tank approximately 3" clear of the bottom, the jets being alternatively directed to the sloping surface and the pump well.

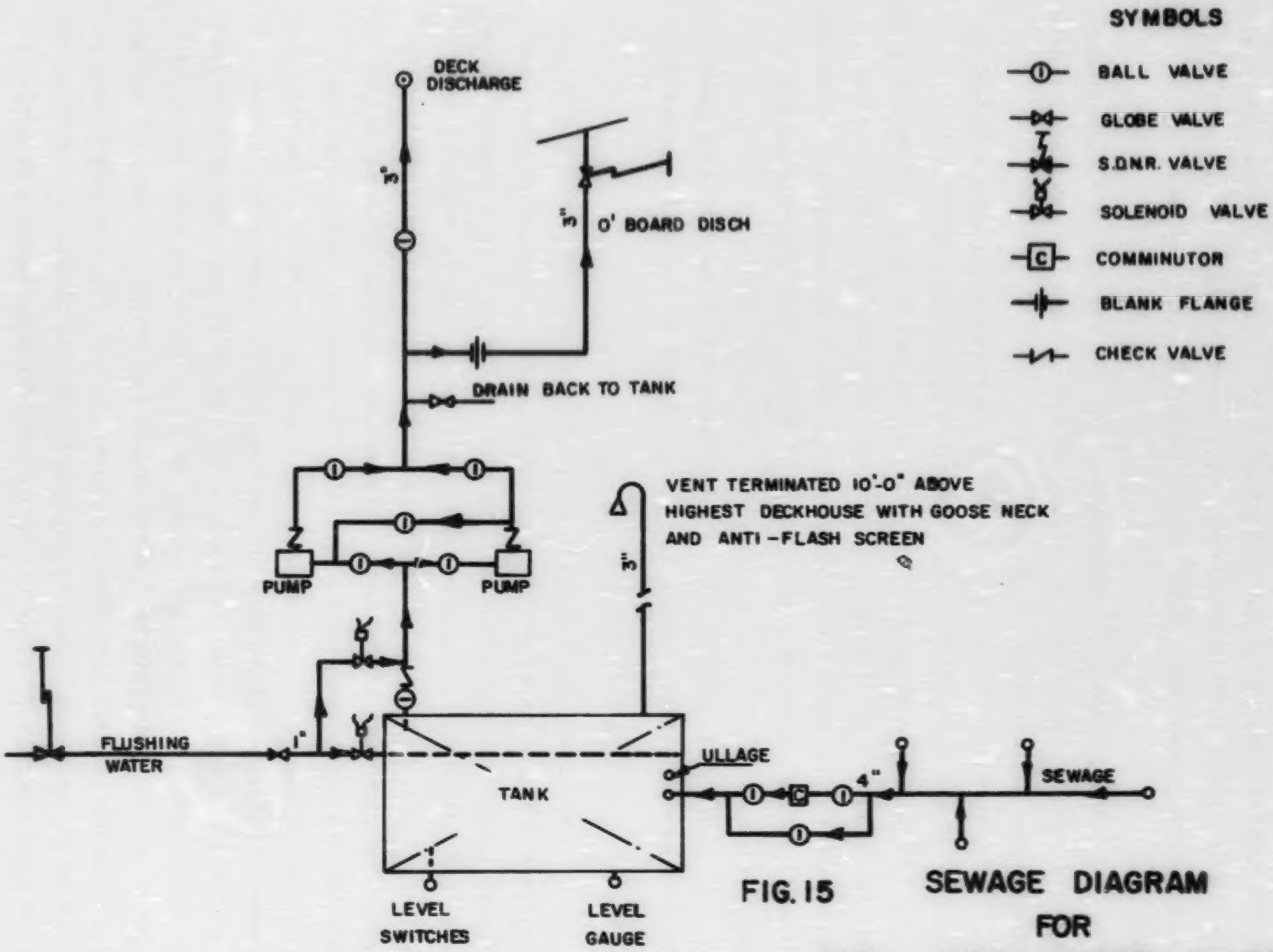

SYMBOLS
BALL VALVE
GLOBE VALVE
S.D.N.R. VALVE
SOLENOID VALVE
C
COMMINUTOR
BLANK FLANGE
CHECK VALVE
DECK DISCHARGE
3"
3"
O' BOARD DISCH
DRAIN BACK TO TANK
PUMP
PUMP
VENT TERMINATED 10'-0" ABOVE HIGHEST DECKHOUSE WITH GOOSE NECK AND ANTI-FLASH SCREEN
3"
FLUSHING WATER
1"
TANK
ULLAGE
4"
SEWAGE
LEVEL SWITCHES
LEVEL GAUGE

FIG. 15 SEWAGE DIAGRAM FOR SMALL TANK (900GAL & LESS)

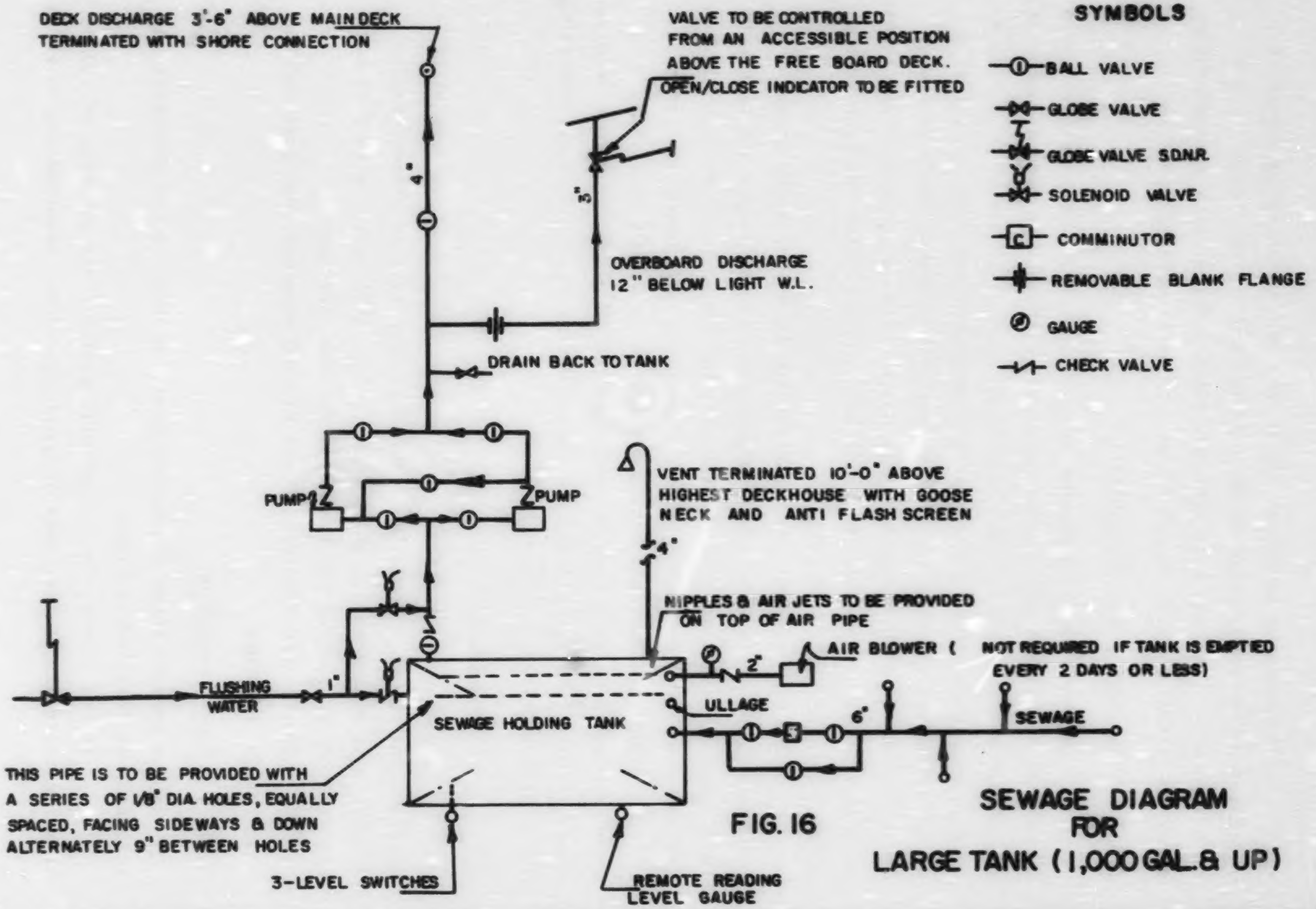

DECK DISCHARGE 3'-6" ABOVE MAIN DECK
TERMINATED WITH SHORE CONNECTION
4"
VALVE TO BE CONTROLLED
FROM AN ACCESSIBLE POSITION
ABOVE THE FREE BOARD DECK.
OPEN/CLOSE INDICATOR TO BE FITTED
5"
OVERBOARD DISCHARGE
12" BELOW LIGHT W.L.
DRAIN BACK TO TANK
PUMP
PUMP
VENT TERMINATED 10'-0" ABOVE
HIGHEST DECKHOUSE WITH GOOSE
NECK AND ANTI FLASH SCREEN
4"
NIPPLES & AIR JETS TO BE PROVIDED
ON TOP OF AIR PIPE
AIR BLOWER (NOT REQUIRED IF TANK IS EMPTIED
EVERY 2 DAYS OR LESS)
2"
ULLAGE
FLUSHING
WATER
1"
SEWAGE HOLDING TANK
6"
SEWAGE
THIS PIPE IS TO BE PROVIDED WITH
A SERIES OF 1/8" DIA HOLES, EQUALLY
SPACED, FACING SIDEWAYS & DOWN
ALTERNATELY 9" BETWEEN HOLES
3-LEVEL SWITCHES
REMOTE READING
LEVEL GAUGE
SYMBOLS
BALL VALVE
GLOBE VALVE
GLOBE VALVE SDNR.
SOLENOID VALVE
C COMMINUTOR
REMOVABLE BLANK FLANGE
GAUGE
CHECK VALVE

FIG. 16

SEWAGE DIAGRAM
FOR
LARGE TANK (1,000 GAL. & UP)

The cleaning mode consists of two tank cleaning cycles of 15 seconds duration each, followed by one pump and system cleaning cycle of 15 seconds. The pump will continue running for a short period of time after the cleaning cycle to ensure the system is drained properly.

3.8.4 Air supply and distribution

In those tanks which need aeration, an air supply header should be mounted inside the tank as low as possible and fitted with a number of adjustable air diffusers of the ball check type. The number of air diffusers to be fitted depends on the actual length of the tank. One diffuser at 12" intervals is considered sufficient, i.e., from 8 to 18 in number for the tanks described herein. This necessitates a compressed air supply at approximately 6 psig, of 96 to 144 CFM. Each orifice can be adjusted for a delivery of 6 to 12 CFM each.

It is considered good practice to set the delivery at the orifice in smaller tanks slightly higher than in the larger tanks. Where 10 or less diffusers are fitted, the setting should be about 10 to 12 CFM each, and 6 to 8 CFM each where more than 10 diffusers are fitted.

The volume of air actually required to prevent the wastes from becoming anaerobic is very small but the forgoing air volume requirements include that for keeping the tank contents agitated, thus preventing the solids settling.

3.8.5 Valves and fitting

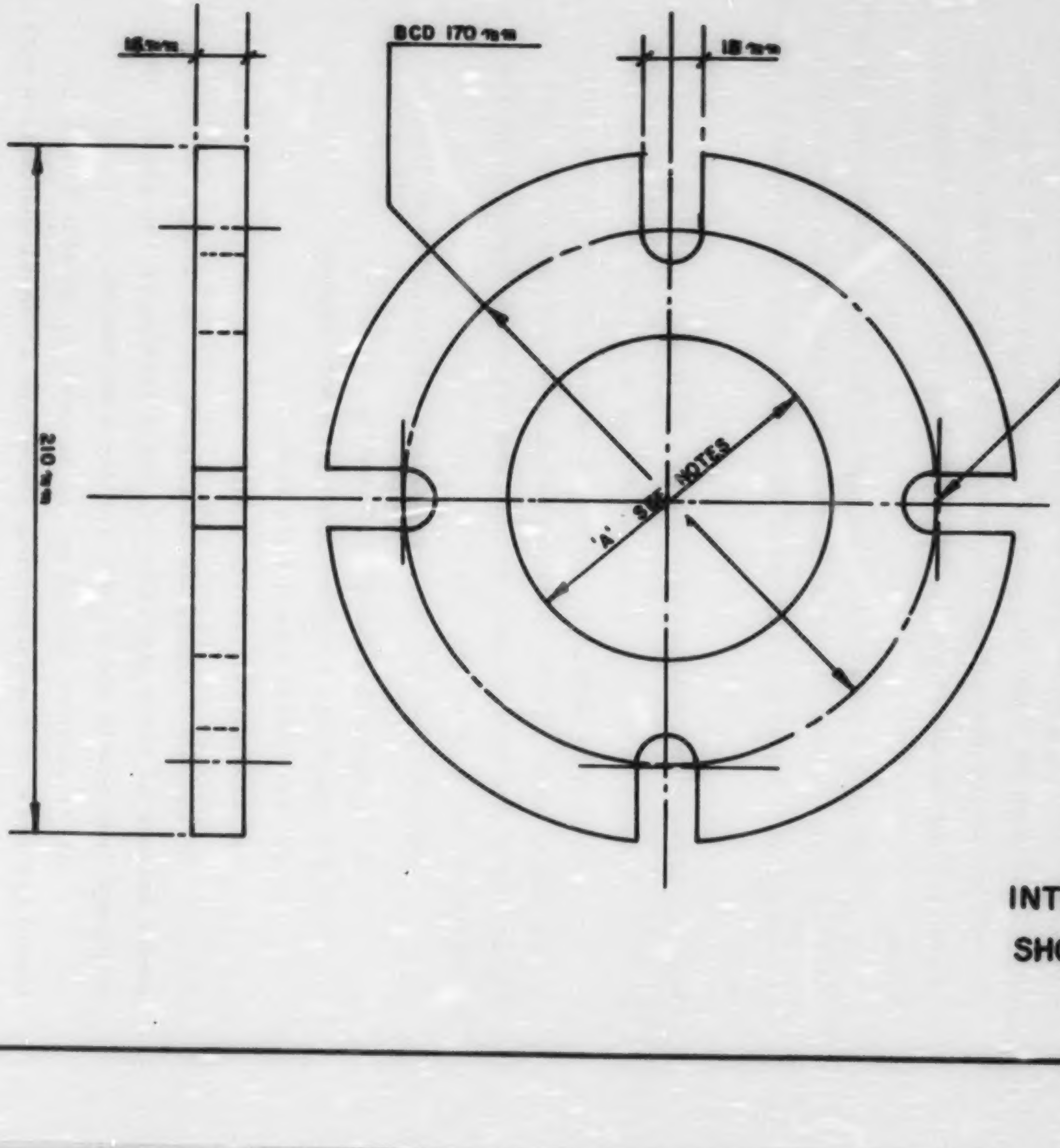
No brass components should be used in contact with the liquid handled. All valves should be of the full bore type to prevent sludge accumulating behind seats, valve stems, etc. Ball valves with full bore openings are considered the best type for this service.

Smooth bore fittings should be used whenever practical for the same reasons as above.

3.9 Shore connection

A special shore connection should be supplied to international standards as detailed in Figure 17.

In some cases, the owners will prefer their own type of connection to suite their particular needs or quick-disconnect requirement, in which


16 mm
BCD 170 mm
18 mm
210 mm
'A' SEE NOTES

NOTE:

'A' TO SUIT O.D. OF PIPE UP
TO A MAXIMUM I.D. OF 100 mm

4 X 16 mm DIA. BOLTS.
& NUTS

STEEL FLAT FACE WITH
2 mm THK. RUBBER GASKET.

FIG. 17
INTERNATIONAL STANDARD
SHORE CONNECTION

case an adapter piece must be provided having the international flange on one end and a mating connection to fit the ship's connection on the other end. Care must be taken to ensure that this discharge connection is distinctly different from any other deck connection.

A deck discharge station should be provided, preferably one port and one starboard, but the owner may select one side only if the particular trade of the vessel allows this. However, the station should be in an accessible location which will enable the shore connection to be made with the least amount of bends, also the station should be remote from the FW filling station and be clearly marked "Sewage Discharge Station". Care should also be taken to ensure the connection does not cause an obstruction to the passage of crew members in the performance of their duties and, in passenger ships, should be kept out of the passenger areas.

The deck discharge station should include pump controls, shutoff valve and pump running lights as further described in the Section 3.11.1 of this study. A sketch of the deck control station is included in Figure 18.

3.10 Alarms and Indicating Devices

The various alarm requirements are described in Section 3.11.1.

All alarms should be displayed on the engineers alarm panel in the engine room. Level indicators should be provided on the tank for either local or remote readout of the tank contents, depending on the location of the tank in the ship.

Various types of level indicators are available as follows:

a) Gauge glass for direct reading
b) Diaphragm type for local or remote readout
c) Air bubble type remote readout
d) Electrical resistance type remote readout

Of the above types, the gauge glass on the tank is not recommended because of the probability of sludge forming in the glass. The diaphragm type should not be used for the same reason.

Level switches should not be actuated by movable floats but should either be of the submersible probe type or be in conjunction with

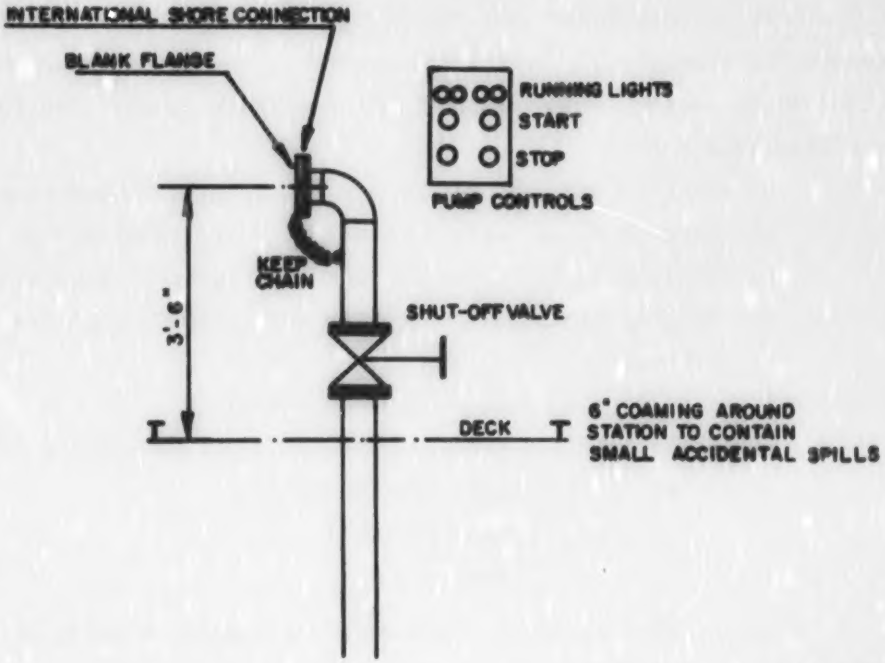

INTERNATIONAL SHORE CONNECTION
BLANK FLANGE
RUNNING LIGHTS
START
STOP
PUMP CONTROLS
KEEP CHAIN
SHUT-OFF VALVE
3'-6"
DECK
6" COAMING AROUND STATION TO CONTAIN SMALL ACCIDENTAL SPILLS

FIG. 18 DECK DISCHARGE STATION

a continuous readout remote level indicator of the variable electrical resistance type.

An ullage opening has been included in the design of the holding tanks for the purpose of periodically calibrating the level indicating device. This ullage opening is kept closed by a bolted blank flange when not in use.

3.11 Controls and Electrical Installations

3.11.1 Control system

It is considered that the sewage discharge system should be fully automatic in operation after initial start-up, and considering the following variations in sewage holding tanks, the required automatic controls should be as described herein.

a) Small holding tanks, no aeration, but with comminution.
b) Large holding tanks with aeration and comminution.
c) Holding tanks in conjunction with recirculation systems.
d) Holding tanks in conjunction with flow-through treatment systems.

The control system for (a) above would consist of:

Three (3) level switches mounted in the tank sensing the
following levels - tank 90% full
tank 50% full
tank empty

These level switches would activate alarms, running lights, warning lights and timer.

The level switch at 50% full would activate a red warning light on the engine room alarm panel showing tank 50% full and giving warning to the engineer that the tank should be emptied at the earliest opportunity. This level is chosen to give the engineer ample warning to empty the tank, and because the design capacity of tank is based on 50% full in most cases.

The level switch at 90% full would activate an audible alarm and make the above red light show flashing.

The level switch of tank empty would activate a series of events as follows:

When tank is ready for shore discharge after connection has been made to the shore discharge pipe, the officer in charge will press the pump start button located at the discharge station. This will start the appropriate pump on line and commence discharge. When the tank is empty the low level switch will start a timer which in turn will activate the following devices:

Open the clean water valve for flushing of tank after 1 second.
Close the clean water valve for flushing of tank after 15 seconds.
Open the clean water valve for flushing the tank after 20 seconds.
Close the clean water valve for flushing of tank after 35 seconds.
Open the clean water valve for flushing pump and pipe lines after 40 seconds.
Close the clean water valve for flushing pump and pipe lines after 55 seconds.
Shut down the pump after 60 seconds.
Total timer run 60 seconds.

At the discharge station a green light would show during the normal discharge cycle. This light would show flashing during the 60 second flushing cycle and go out on completion of the cycle.

A red light would show on-pump failure during any part of the cycle after which the standby pump can be started by pushbutton from the discharge station on deck.

Where it is desirable not to employ an automated flushing cycle, a manually operated cycle, conforming to the above timing can be used. In such cases the solenoid valves (see Figures 15 and 16) would have to be replaced by appropriate globe valves, one of them being SDNR, and the timing sequence shown in Figure 19 need not be installed. The control system for (b) would consist of:

Three (3) level switches mounted in the tank sensing the
following levels - tank 90% full
tank 50% full
tank empty

These level switches would control the same system as under (a) in the foregoing. In addition, this system can incorporate continuous aeration of the tank contents by forced ventilation as shown on the schematics.

One compressor could be used, running continuously. Audible and visual alarm could be provided on failure. One comminution unit should be used, running continuously, bypass with manual valve being provided. Audible and visual alarm could be provided on failure of the unit.

The holding tanks (c) and (d) are basically the same as (a), so the control system required can be identical. On very small tanks the level switch at 50% full could be omitted provided a suitable remote reading level gauge is fitted showing the tank level at the engines control stand. These tanks receive the sewage from the downstream side of the treatment plant and would hold excess of sewage until it can be pumped ashore at a discharge station.

3.11.2 Electrical installations

All external cabling should be cross-linked polyethylene insulated, impervious sheathed and bronze wire armoured, C.G.E. Specification 8240-D or as approved by the Marine Regulations Branch, Ministry of Transport.

Electrically operated components, such as contactors, relays etc. should be designed to remain closed under normal impact conditions and to have amply rated "seal-in" force and contact areas.

The local control and alarm panel should be fitted in the vicinity of the holding tank with the remote starting panel at the discharge station and should be suitable for operation from 120/1/60 or 120/1/50 as may be the case.

The rinsing cycle should be fully automatic and controlled by one timer actuating four separate cams, and also stopping the discharge pump at the end of the rinsing cycle as described in the foregoing "Control system" section.

Alarm indications should be on open circuit.

For reference, see electrical schematics, Figures 19 to 24. Auxiliary pumps such as aeration compressors, comminutor units, and discharge pumps should be energized from the ship's service distribution system.

3.12 Nameplates

Pumps, motors, starters, compressors and comminutors should have manufacturers' usual nameplates giving particulars of the equipment. Piping and valves should have direction of flow indication and all valves should have nameplates marked "SEWAGE" followed by their function in the system.

The holding tank should be fitted with a plate giving the capacity and pressure head.

The shore connection station should have a plate marked:

"Sewage Discharge Station"

The sewage pump control panel should have a plate marked:

"Sewage Pumps"

and the stop, start buttons and running lights should be clearly marked.

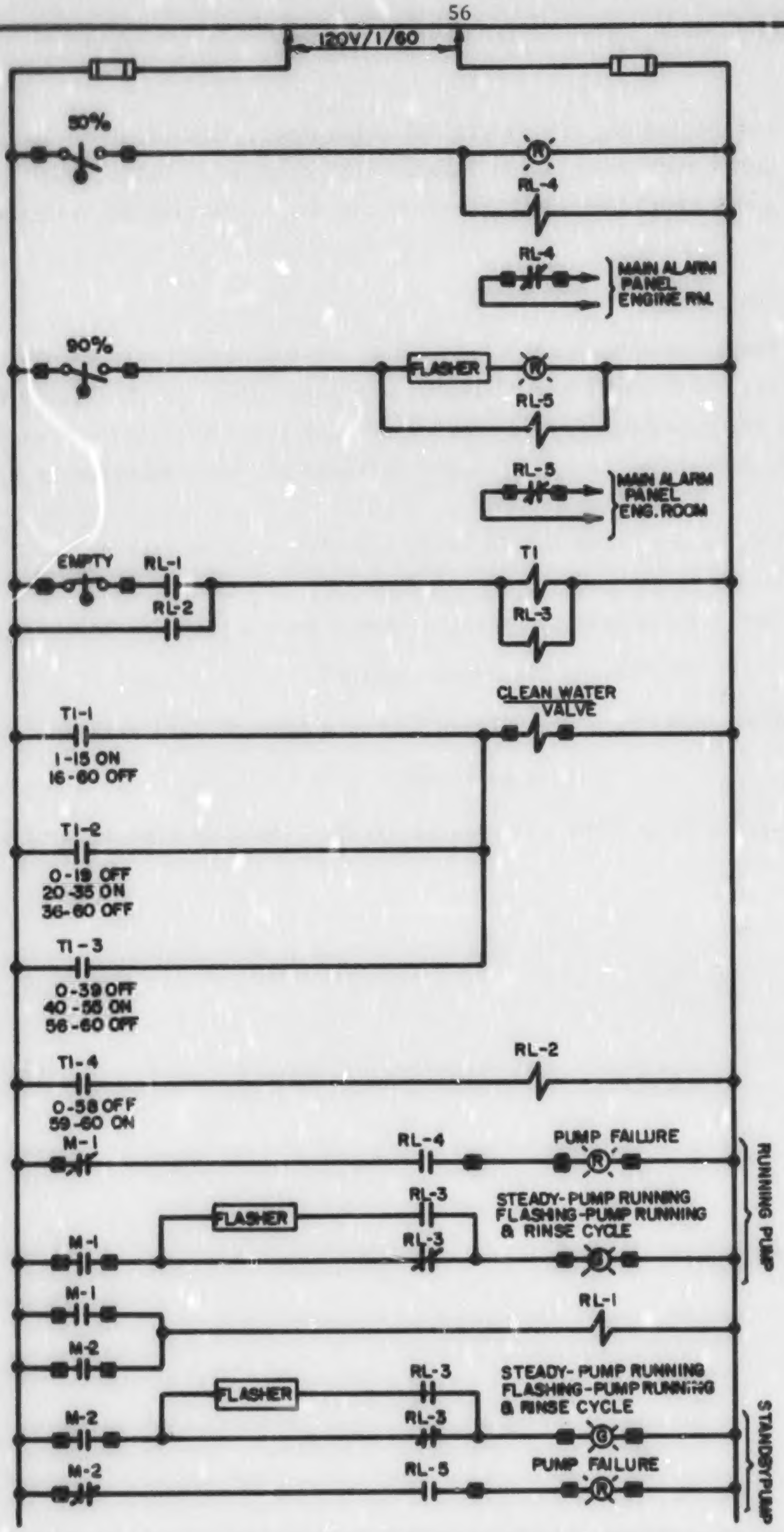

120V/1/60
50%
R
RL-4
RL-4
MAIN ALARM PANEL ENGINE RM.
90%
FLASHER
R
RL-5
RL-5
MAIN ALARM PANEL ENG. ROOM
EMPTY
RL-1
RL-2
T1
RL-3
T1-1
1-15 ON
16-60 OFF
CLEAN WATER VALVE
T1-2
0-19 OFF
20-35 ON
36-60 OFF
T1-3
0-39 OFF
40-55 ON
56-60 OFF
T1-4
0-58 OFF
59-60 ON
RL-2
M-1
RL-4
PUMP FAILURE
R
M-1
FLASHER
RL-3
RL-3
STEADY-PUMP RUNNING
FLASHING-PUMP RUNNING & RINSE CYCLE
G
RUNNING PUMP
M-1
M-2
RL-1
M-2
FLASHER
RL-3
RL-3
STEADY-PUMP RUNNING
FLASHING-PUMP RUNNING & RINSE CYCLE
G
M-2
RL-5
PUMP FAILURE
R
STANDBY PUMP

FIG. 19
ELECTRICAL CONTROL SCHEMATIC

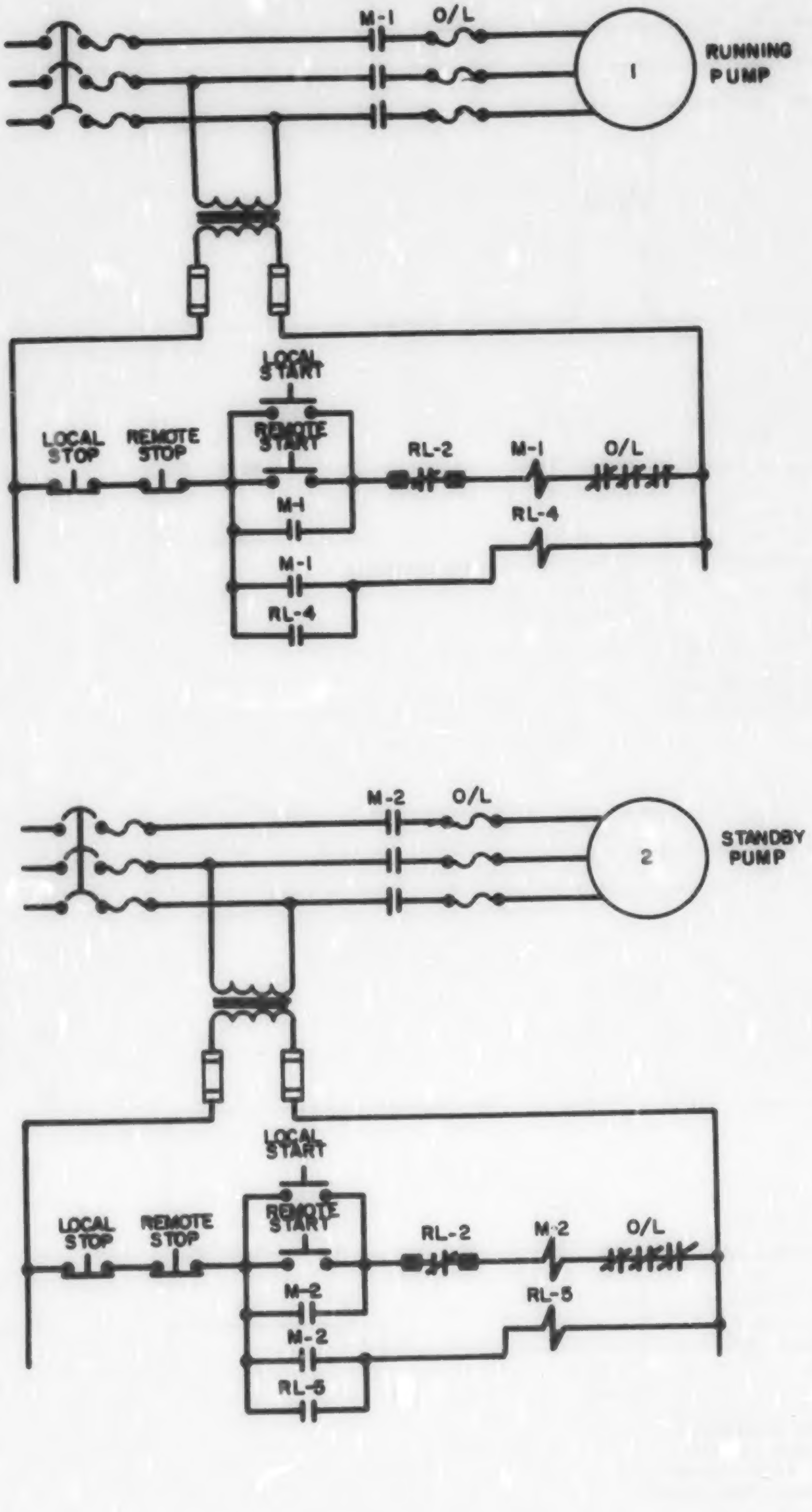

M-1
O/L
1
RUNNING PUMP
LOCAL START
LOCAL STOP
REMOTE STOP
REMOTE START
RL-2
M-1
O/L
M-1
RL-4
M-1
RL-4
M-2
O/L
2
STANDBY PUMP
LOCAL START
LOCAL STOP
REMOTE STOP
REMOTE START
RL-2
M-2
O/L
M-2
RL-5
M-2
RL-5

FIG. 20
ELECTRICAL POWER SCHEMATIC
MOTOR STARTER

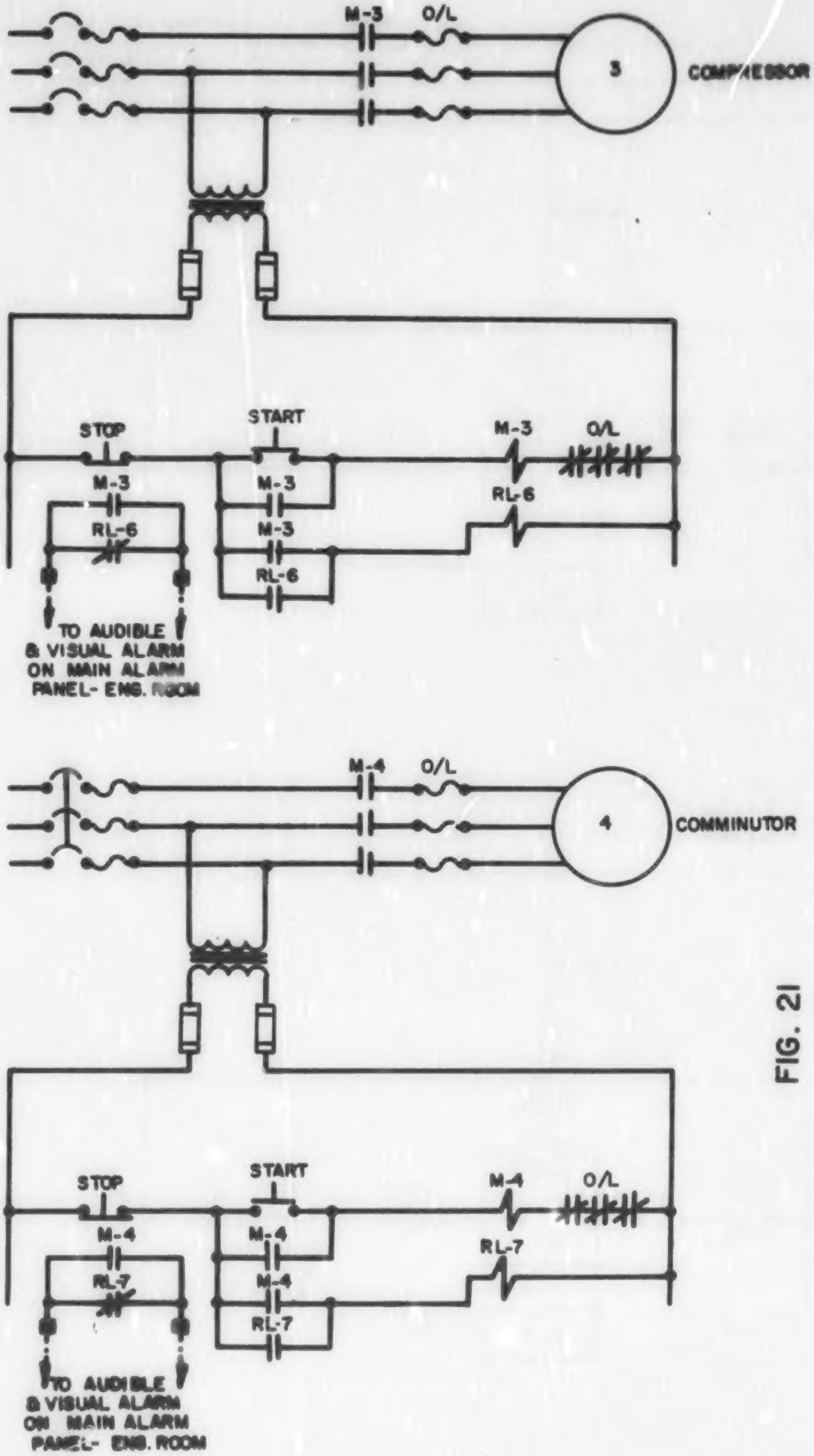
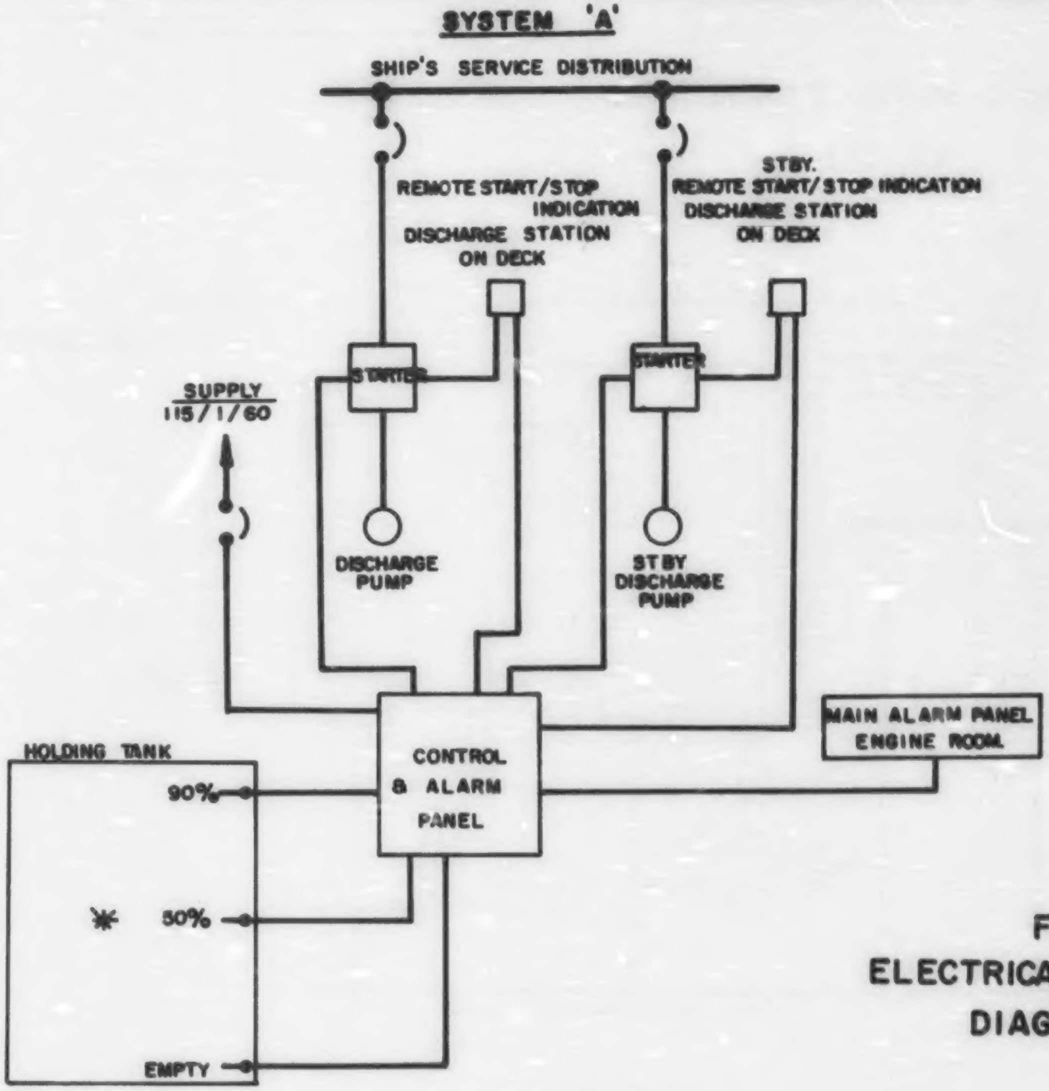

M-3
O/L
3
COMPRESSOR
STOP
START
M-3
O/L
M-3
RL-6
M-3
RL-6
M-3
RL-6
TO AUDIBLE
& VISUAL ALARM
ON MAIN ALARM
PANEL- ENG. ROOM
M-4
O/L
4
COMMINUTOR
STOP
START
M-4
O/L
M-4
RL-7
M-4
RL-7
M-4
RL-7
TO AUDIBLE
& VISUAL ALARM
ON MAIN ALARM
PANEL- ENG. ROOM

FIG. 21

ELECTRICAL POWER SCHEMATIC
MOTOR STARTER


SYSTEM 'A'
SHIP'S SERVICE DISTRIBUTION
REMOTE START/STOP INDICATION
DISCHARGE STATION ON DECK
STBY. REMOTE START/STOP INDICATION
DISCHARGE STATION ON DECK
STARTER
STARTER
SUPPLY 115/1/60
DISCHARGE PUMP
ST BY DISCHARGE PUMP
CONTROL & ALARM PANEL
MAIN ALARM PANEL ENGINE ROOM
HOLDING TANK
90%
* 50%
EMPTY

* OPTIONAL

FIG. 22
ELECTRICAL BLOCK
DIAGRAM

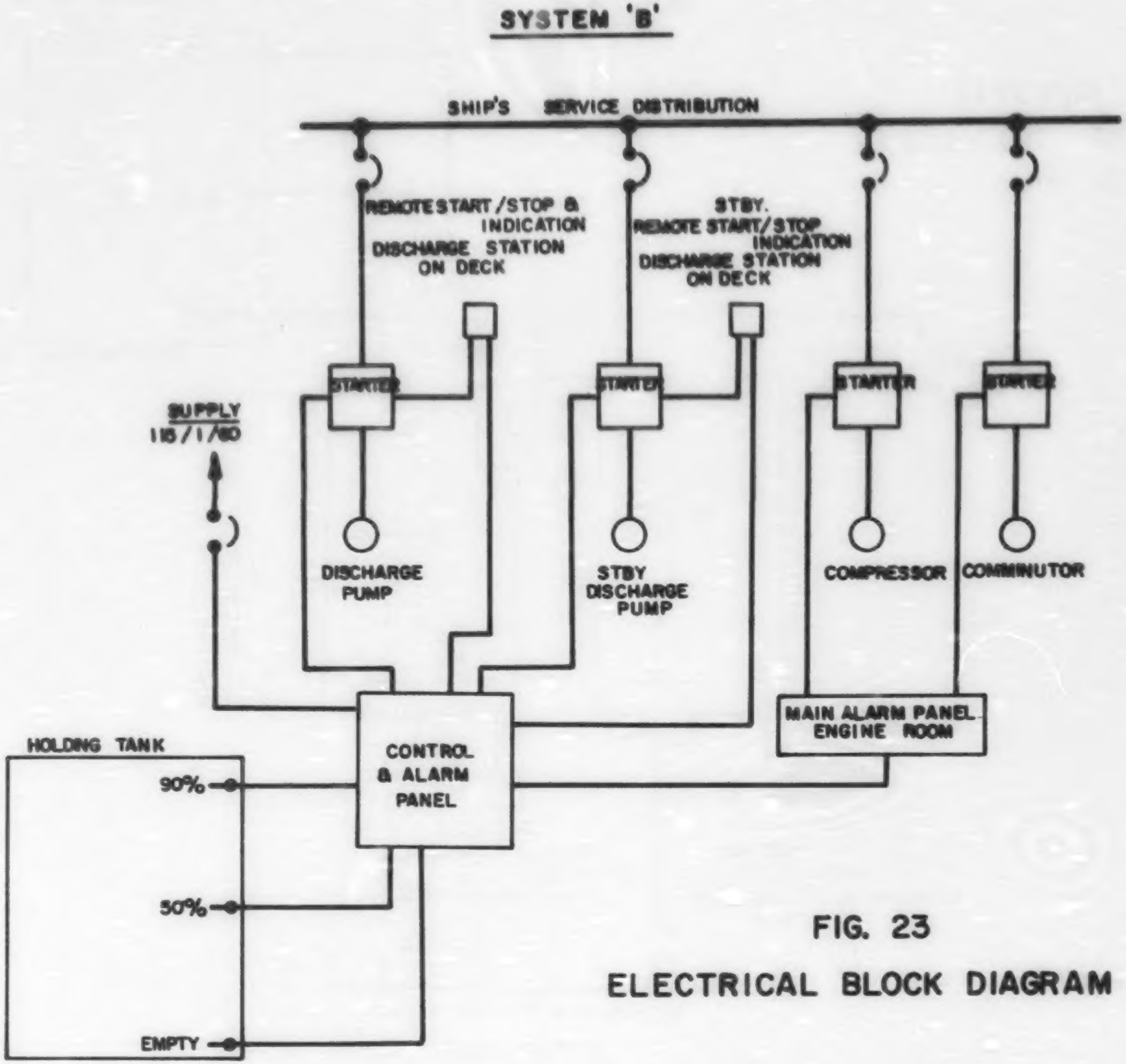

SYSTEM 'B'
SHIP'S SERVICE DISTRIBUTION
REMOTE START/STOP & INDICATION DISCHARGE STATION ON DECK
STBY. REMOTE START/STOP INDICATION DISCHARGE STATION ON DECK
STARTER
STARTER
STARTER
STARTER
SUPPLY 115/1/60
DISCHARGE PUMP
STBY DISCHARGE PUMP
COMPRESSOR
COMMINUTOR
MAIN ALARM PANEL ENGINE ROOM
HOLDING TANK
CONTROL & ALARM PANEL
90%
50%
EMPTY

FIG. 23

ELECTRICAL BLOCK DIAGRAM

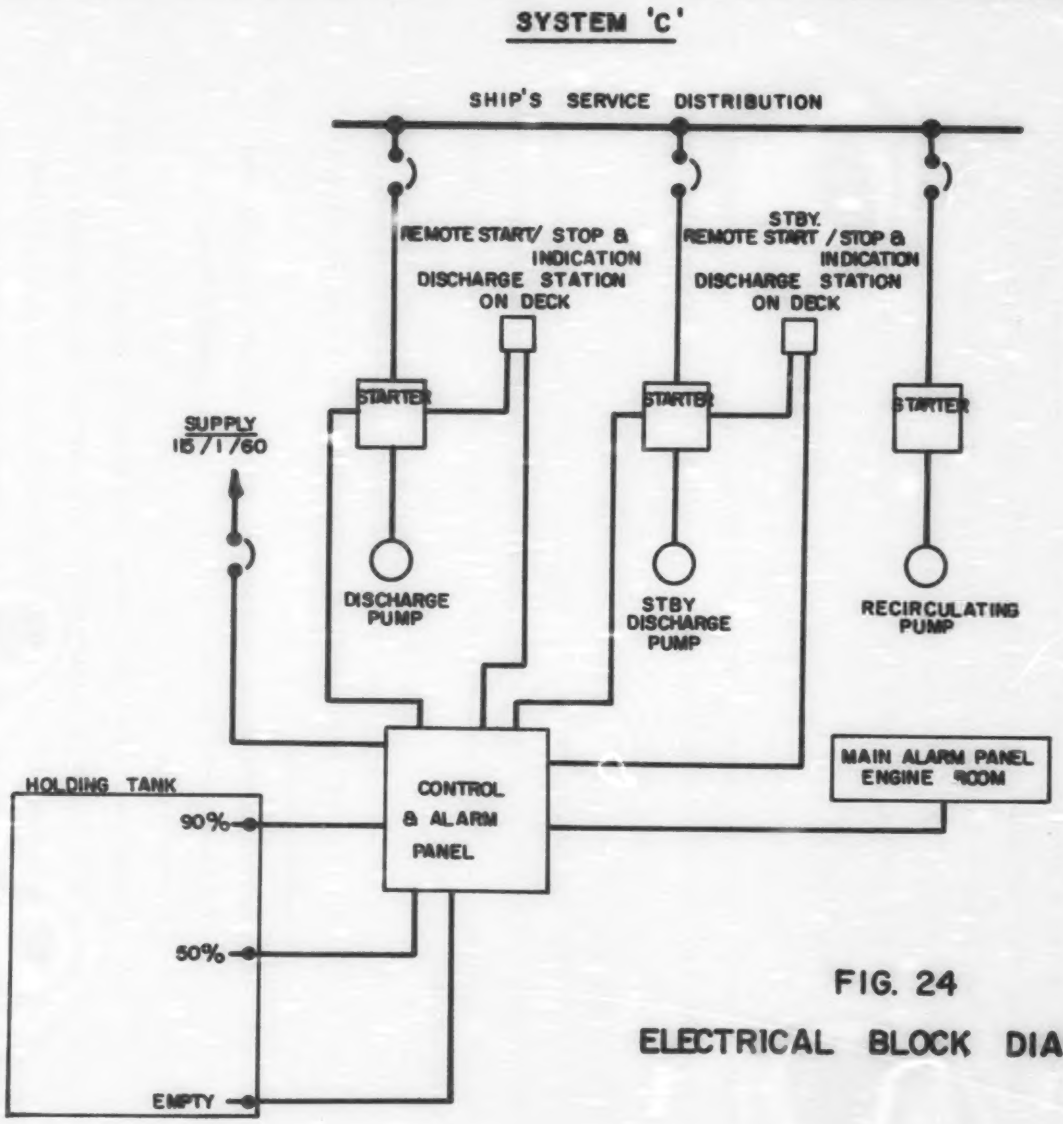

SYSTEM 'C'
SHIP'S SERVICE DISTRIBUTION
REMOTE START/ STOP & INDICATION DISCHARGE STATION ON DECK
STBY. REMOTE START / STOP & INDICATION DISCHARGE STATION ON DECK
STARTER
STARTER
STARTER
SUPPLY 115/1/60
DISCHARGE PUMP
STBY DISCHARGE PUMP
RECIRCULATING PUMP
CONTROL & ALARM PANEL
MAIN ALARM PANEL ENGINE ROOM
HOLDING TANK
90%
50%
EMPTY

FIG. 24

ELECTRICAL BLOCK DIAGRAM

4 OPERATIONAL AND MAINTENANCE PROCEDURES

4.1 Operation

The system operation would be generally as described under Sections 3.8 "Piping and Pump Detail" and Section 3.11 "Controls and Electrical Installations". As part of the discharge operation, all manually operated valves should be set in the required open or shut position before commencing the discharge cycle. Preferably, the necessary pump valves should be open to enable the operator at the discharge station to start either pump without having to go in the engine room. As part of the operational duties, the pressure of the air supply should be checked every watch and also a record kept of the liquid level in the tank.

4.2 Maintenance

A simple system of this nature needs very little daily routine maintenance. The only daily routine should be to check for leaks and check out any out-of-the-ordinary reading of the air pressure or liquid level. The air filter on the compressor should be cleaned or renewed when required.

The comminutor as well as the compressor does not normally need maintenance once running except for cleaning or renewal of the air filter on the compressor. On a yearly basis, the following maintenance should be performed:

1) Steam out all tank, pipe and pump intervals to the satisfaction of local health authority prior to start of maintenance work.
2) Remove comminutor, dismantle, clean, check for wear and replace parts as required, all as per manufacturer's instructions.
3) Check pump seals and renew or repair as required. Follow manufacturer's instructions for further maintenance.
4) Tank should be visually checked inside and outside for paint damage. Inside to be cleaned thoroughly using high pressure water hose through manhole. Any paint damage inside is to be made good.

5) Air diffusers should be cleaned and replaced as required.

6) Normal maintenance is required on the electrical equipment.

5 TESTING

5.1 Tank Pressure Test

After installation of a holding tank system, it is recommended that the system should be tested for leaks by a pressure test to 1.5 times the rated pressure head indicated on the nameplate on the holding tank.

5.2 System Running Test

Before putting the system into service, the tank should be filled with clean water to the 50% full level, approximately, and the air compressor started to check that the correct air pressure is registered on the gauge. Additionally, the level indicating device should be calibrated.

The comminutor should be started and checked to see that the motor is running satisfactorily.

The discharge pumps should be started and the water in the tank discharged to see if the pumps and flushing cycle are working satisfactorily.

6 ECONOMIC IMPACT

6.1 General

There are many variables in the calculation of the economic impact of installing a holding tank system in a vessel, some of which are difficult to assess accurately. Estimated costs can be determined, however, which will serve as a basis of comparison between holding tank systems and other alternatives available. In that context accuracy becomes of reduced importance provided all systems are estimated on the same basis. Estimates are based on conditions prevailing in 1974.

The cost of a system affects the ship costs in the following ways:

a) Capital cost of the system
b) Operating costs of the system
  1) Running costs (i.e. chemical, power, labour)
  2) Cost of lost deadweight
  3) Cost of lost time when pumping out
  4) Shore facility fees
c) Maintenance costs

Each of these costs has been considered in relation to the classes of ships as listed in Table 1, Section 2.2, to show the comparison between a holding tank system and the following alternatives:

a) Direct overboard discharge
b) A vacuum system
c) A recirculating system
d) A flow-through treatment system
e) A holding tank system combined with systems b), c) and d) to reduce capacity.

To complete the comparison, an effort has been made to show the cost comparison between the above systems when fitted to ships under construction and retrofit conversions.

6.2 Capital Costs

The capital costs of all the systems can be broadly broken down into two categories as follows:

a) Drain piping from toilets and urinals.

b) The device (holding tank or treatment tank) together with associated equipment for treatment and discharge (pumps, compressors, discharge piping, vent etc.).

It will be noted that the supply piping to the toilets and urinals has been omitted. The costs would probably be the same for all systems in a new ship. There will, however, be an additional cost for a vacuum system for the special toilets.

The drain piping systems would also be approximately the same for all systems except the direct overboard and the vacuum systems. The vacuum systems are cheaper because of the smaller diameter pipe and because they are not dependent on gravity, which allows for easier installation.

These guidelines have so far not been concerned with the number of toilet and urinal fixtures as the systems are sized to suit the flow rate, which is based on the number of people and type of water usage. When considering costs, however, the number of fixtures does have a bearing on the estimate, as does their location in the ship and, therefore, these numbers have been estimated on the basis of good ship practice.

Laker	32	(22 aft, 10 forward)
Tanker	32	(all aft)
Dredge, large	10	
Passenger Vessel, large	40	
Passenger Vessel, water bus	3	(2 passengers aft, 1 crew forward)
Tug	2	
Fishing Vessel	1	
Dredge small	1	

For the holding tank systems, the installed costs of the tank and associated equipment, as previously recommended herein, have been calculated and the results are shown in Figure 25. The inserts in Figures 5 to 12 in Section 3.4 give the recommended tank capacities in gallons for each class of ship for each type of water usage system. Using these capacities it is easy to obtain the approximate cost of the holding tank from Figure 25. To these figures must be added the drain piping

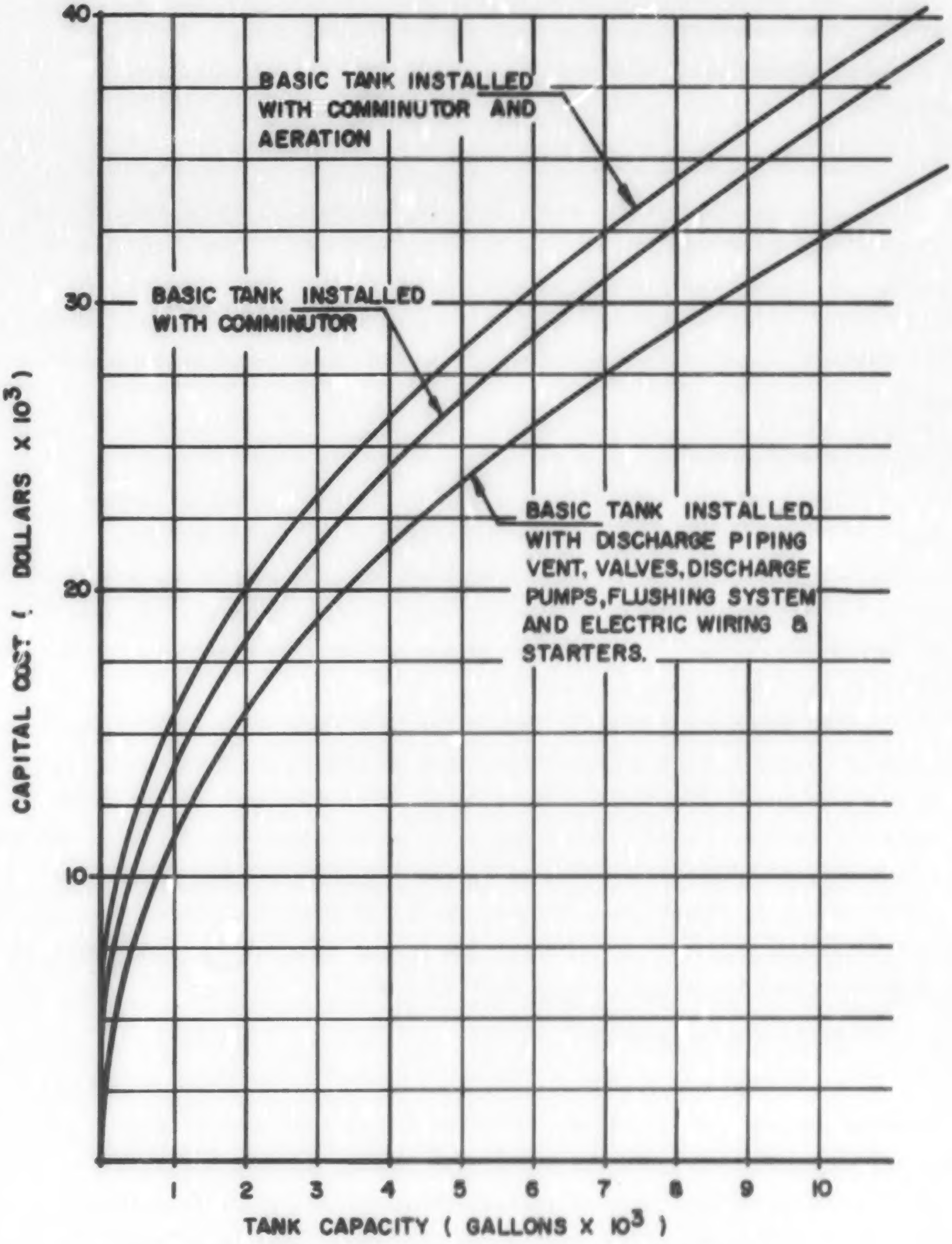


FIG. 25 CAPITAL COST OF TANKS (INSTALLED)

costs, and the combined totals, for each ship are shown in Table 4 for conventional water usage.

The total costs shown in Table 4 are, in fact, the capital costs involved in fitting holding tank systems to new ships. In order to evaluate these costs, they must be related to other alternatives available.

6.2.1 Direct overboard systems

This was the system extensively in use prior to the advent of various sewage treatment systems and it is in fact still in use in some vessels. It is, of course, the cheapest because it is the simplest. It is the basic system on which to build up a cost comparison. The estimated costs for each class of ship for this system are shown in Table 5 for new ships.

6.2.2 Vacuum systems

These systems have attracted much attention in recent times because of the significant reduction in water use and their ease of installation. They are not treatment systems and are, therefore, usually fitted in conjunction with another system such as incineration. Because of the reduced water usage they can be used as a holding tank system without additional tankage in some cases.

The costs for vacuum systems range from about $6000 in the small ships up to about $32,000 in the large ships on the basis of the comparative costs. When combined with the recommended holding tank system sized to suit the low water usage, the total costs would range from $6500 to $50,000, respectively, for new ships. It will be seen, therefore, that installing a vacuum system is advantageous because the total costs give about 50% reduction in the small ships and about 33% in the large ships, when compared to a conventional water use holding tank system.

6.2.3 Recirculating systems

These systems show an even greater reduction in water usage than the vacuum systems and, therefore, they too can be used as a holding tank system without the need for additional tankage in some cases.

The installed costs of recirculating systems range from about $1000 for an individual toilet system for the small ships up to about

VESSELS	COST OF HOLDING TANK SYSTEM $	DRAIN PIPING $	TOTAL COST $
LAKER	66,750	7,350 ✓	74,100
TANKER	66,750	3,950	70,700
DREDGE LARGE	66,750	2,700	69,450
PASSENGER VESSEL LARGE	31,750 *	7,100	38,850
PASSENGER VESSEL WATER BUS	13,750 *	500	14,250
TUG	23,250	350	23,600
FISHING VESSEL	12,500	350	12,850
DREDGE SMALL	12,500	350	12,850

* PASSENGER VESSEL TANKS WITHOUT AERATION.

✓ LAKER PIPING INCLUDES FORWARD LIFT STATION

TABLE 4 CAPITAL INSTALLED COSTS OF HOLDING TANK SYSTEMS. (NEW SHIPS)

VESSELS	COST OF DIRECT OVERBOARD DRAINS $
LAKER	2,500
TANKER	2,000
DREDGE LARGE	1,000
PASSENGER VESSEL LARGE	2,500
PASSENGER VESSEL WATER BUS	200
TUG	200
FISHING VESSEL	200
DREDGE SMALL	200

TABLE 5 CAPITAL INSTALLED COSTS OF DIRECT OVERBOARD DRAIN PIPING. (NEW SHIPS)

$28,000 for the largest ship on the basis of the comparative costs. When combined with the recommended holding tank system, the total costs will range from $1200 for the smallest to $39,000 for the largest system, both for new ships. On the comparative basis, the capital cost for the recirculating system with holding tank results in a saving of approximately 90% for the small ships to 48% for the large ships so that here again the installation of a system to reduce the water flow is advantageous on a capital cost basis.

6.2.4 Flow-through systems

These systems normally use the same amount of water as a conventional water usage system, although they could be combined with a vacuum type system with modifications to the unit to suit the lower water flow. The advantages of this type of system, when compared to the vacuum and recirculating systems, are that no special toilets and no special chemicals are required other than chlorination.

The approximate costs for flow-through systems range from about $12,000 for the small vessels to about $35,000 installed for largest aerobic system on the comparative basis. When combined with the recommended holding tank system for a conventional water usage system, the total costs would range from about $25,000 to about $110,000 for the assumed retention period (per Table 3). If the system was combined with a vacuum system and a holding tank system the range would be reduced to about $19,000 for the small ships to $80,000 for the large ships, showing once again that a reduction in water usage results in a saving in capital cost.

6.3 Operating Costs

The operating costs as previously mentioned fall into four categories as follows.

6.3.1 Running costs

The running costs of a holding tank system include the electrical power consumption costs and crew labour in checking the air pressure daily. Only the comminutor and air compressor are normally running and both are of fractional horsepower and, as the discharge pumps only run for about half an hour during pump-out, the electrical costs should be so minimal that they can be ignored in the overall cost of running a ship. Furthermore, the generators would be running anyway and the power consumed would be a small fraction of the generated power. The crew costs, too, can be ignored, as it is only a matter of taking a reading of the pressure gauge during the normal rounds of the engineer on watch and this is negligible.

When combined with a flow-through system, there would be approximately two hours per day for operating the unit plus about 50 cents per day for chlorination, which would total approximately $3400 per year assuming nine months per year and an average of $6 per hour for an oiler.

With a vacuum system, the cost would be approximately the same except for the chlorination so that one could allow approximately $3200 per year for this type of system.

When combined with a recirculating system, the cost would be increased for the additional chemicals and, in this case, the estimated total would be about $3700 per year.

6.3.2 Cost of lost deadweight

This cost would apply only to the cargo carrying ships such as the laker, tanker, and fishing vessels. The dry weight of all systems is negligible when compared to the weight of the vessel, so only the added liquid weight need be considered.

On a laker or tanker this would amount to about 30 gallons per man per day for the conventional water usage system which gives the maximum flow. This would mean a total of 900 gallons per day for a crew of 30 men. The system starts empty, however, and the addition of 900 gallons per day is much less than the fuel consumed which, for a laker or tanker with 6000 HP engines and 500 HP ship service generators, would amount to 3600 gallons per day at full power on the basis of 12 hours per day. Similarly, for a fishing vessel with two crew the sewage would give only 60 gallons per day while the fuel consumed would be approximately 170 gallons per day on the same basis of a 12 hour day, full power, with 300 HP for engine and generator.

Therefore, even allowing for time in port when the engines are idle and reduced speed in harbour approaches, it can be assumed that there will, in fact, be no loss in deadweight due to the fuel consumption cancelling out the added sewage weight.

6.3.3 Cost of lost time when pumping out

The cost of time lost to the vessel when pumping out the sewage to the shore facility must be considered but, in actual practice, the time can be ignored if the recommendations are followed, because for all but the passenger ships and the large dredge, the pump-out time will coincide with the fuelling. In the case of the passenger ships or the large dredge, the pump-out time will still be during normal operating hours of the vessel, that is, while passengers are loading or unloading or while on contract in the case of a dredge pumping out to a barge which is brought alongside. This reasoning is, of course, dependent on the availability of a suitable shore reception facility.

6.3.4 Shore facility fees

The fees which will be charged by a shore facility to receive the sewage from a ship are very difficult to assess because at the moment there are no facilities available for commercial vessels. It is known, however, that the fees will be based on three factors as follows:

1) the fee that the adjoining municipality will charge the shore facility operator, to accept the sewage into the municipal sewage treatment system;
2) the cost of the actual pumping out in man-hours of labour and cost of power consumed; and,
3) the amortisation cost of the shore facility which will depend on the capital cost of the facility, the frequency of pump out and gallons handled per year, and the anticipated life of the shore facility.

A study of shore reception facilities has also been carried out for the Department of the Environment. *

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* M.M. Dillon Ltd., Development of Design Guidelines for Shore-side Holding Tanks, Environmental Protection Service Report EPS 3-WP-76-2, Ottawa, 1976.

This study furnishes estimates from which a more accurate assessment of the fees can be obtained. However, municipal charges in Ontario range from 60 cents to $1.50 per 1000 gallons for accepting the sewage and a small shore facility in Ogdensburg charges a flat $5 fee for pumping out 500 to 1000 gallons. Several companies in Montreal will provide this service by means of tank trucks and costs range from approximately $100 for 2000 gallons for one company whose trucks have just over 2000 gallons capacity, to $35 per hour, plus $6.35 per hour for a helper, for a company with trucks up to 7000 gallons capacity. The cost when trucks are involved must, of course, include the time it takes to get to and from the ship. Allowing one hour at the ship and two hours travelling time, the cost per 1000 gallons for this second company would be 3 x 5 + 3 x 6.35 ÷ 7, or $17.72 per 1000 gallons. Using a 2000 gallon truck this same company, on the basis of three hours, would cost $73.05 for the 2000 gallons, as the truck cost drops from $35/hr to $18/hr.

On the basis of available figures, the costs can range from a low of $5 per 1000 gallons to a high of $50 per 1000 gallons and, therefore, for the purposes of these guidelines, it has been assumed that a new shore reception facility would charge $25 per 1000 gallons. The fees would then be as shown in Table 6 and it will be seen that where small capacities are involved a minimum fee of $25 has been assumed.

Table 6 indicates the cost per pump out based on sewage only and assumes this is due only when the tank is full (i.e. using the margin allowed). The cost per year has been based on a year of nine months with pump out regularly spaced at the end of the holding times given in Table 3. The cost per year will not change, of course, if the tank is pumped out at the 50% full level, which is the normal level without the margin for delays, because the frequency of pump out would double but the cost per pump out would be halved. The fees are shown for conventional water usage, low water and recirculating water and, again, the saving in costs for reduced water quantities are evident.

6.4 Maintenance Costs

There is virtually no daily maintenance cost for a holding tank system and the estimated yearly cost would be for approximately 130 man-hours, which at the figure of $6 per hour amounts to $780 per year.

VESSEL	CONVENTIONAL WATER				LOW WATER				RECIRC. WATER			
	CAP.	PUMP-OUT FEE $	Nº OF TIMES PER YEAR	TOTAL COST PER YEAR $	CAP.	PUMP OUT FEE $	Nº OF TIMES PER YEAR	TOTAL COST PER YEAR $	CAP.	PUMP-OUT FEE $	Nº OF TIMES PER YEAR	TOTAL COST PER YEAR $
LAKER	15,000	375	36	13,500	2,000	50	36	1,800	900	25	36	900
TANKER	15,000	375	36	13,500	2,000	50	36	1,800	900	25	36	900
DREDGE LARGE	15,000	375	36	13,500	2,000	50	36	1,800	900	25	36	900
PASSENGER VESSEL LARGE	7,500	187·5	201	3,769	900	25	201	5,025	200	25	201	5,025
PASSENGER VESSEL	900	25	252	6,300	100	25	252	6,300	15	25	252	6,300
TUG	3,000	75	18	1,350	300	25	18	450	500	25	18	450
FISHING VESSEL	500	25	36	900	50	25	36	900	10	25	36	900
DREDGE SMALL	500	25	36	475	50	25	36	900	500	25	36	900

TABLE 6 SHORE FACILITY FEES PER YEAR

Allowing for the replacement of gaskets or minor parts, the cost would be about $850 per year for the holding tank.

The yearly maintenance on the other systems could amount to approximately 120 hours for a flow-through system and 140 hours for the vacuum and recirculating systems, giving totals of $720 and $840 on the basis of $6 per man/hour. Again, to allow for the replacement of small parts these figures would be about $850 and $1000, respectively.

When these systems are combined with a holding tank system, then the costs are also combined and the totals would then be $1700 per year for a flow-through system with holding tank and $1850 per year for either a vacuum or recirculating system with a holding tank.

6.5 Retrofit Costs

The costs involved in fitting any system to an existing ship are almost impossible to estimate without detailed knowledge of the ship in question.

The basis of the costs would involve the following:

1) design of system;
2) existing piping to be dismantled where necessary or blanked off;
3) access to be provided for shipping unit;
4) equipment to be moved to make space for unit;
5) cost of time the vessel is out of service;
6) drydocking if required;
7) replacing all toilets if new system includes a vacuum system; and,
8) fitting new system.

For the purpose of this study, it has been assumed that, in all cases, there is sufficient space without moving major items of equipment and access is available even if it means taking the tank into the vessel in pieces. Time out of service and drydocking can be eliminated if the system is fitted during the normal drydocking for inspection and repairs. There will probably be a period of grace before the enforcement of new regulations to existing vessels and, therefore, it is not unreasonable to assume that drydocking would take place without taking the vessel out of service specifically to convert the sewage system.

On this basis then, the cost of fitting a holding tank system to an existing vessel could be fairly close to the cost of fitting a system to a new vessel, especially if it is decided to leave in the vessel as much of the existing piping as possible, rather than dismantling the entire system. If the vessel has any kind of treatment system, flow-through or recirculating, or if it has a vacuum system, then there would probably be no need to change the piping anyway. The holding tank which calls for major change to the piping is the direct overboard discharge system where all the drains would need to be collected together and led to the holding tank. This system, however, is the one in which it would be easiest to leave existing piping with just a short piece dismantled at the toilets and urinals to allow for new connections.

It can, therefore, be assumed that the cost of retrofit work to existing ships would be in the range of 10% extra over new building for the larger ships to 20% extra over new building for the smaller ships. When installing a new vacuum system to an existing vessel, however, the additional cost may increase to 20% for the large ships and 30% for the small ships, due to replacement of the toilets. These additional costs are percentages of the cost of a conventional water usage holding tank system and not 20% or 30% of the combined vacuum and holding tank system.

It should be noted that by fitting pollution control equipment to a vessel the owner may apply for accelerated capital cost allowance under the Income Tax Regulations. This has not been taken into account in this analysis because similar concessions and subsidies apply to new construction installations.

6.6 Grey Water

All the foregoing cost data have been based on the retention of sewage only and, therefore, if it is decided to retain grey water, the costs will increase substantially for the larger ships. This is because the tank size has been limited to 10,000 gallons and additional tankage would be required. The cost should be reduced a little if the grey water is kept separate so that the grey water tanks would not require either aeration or comminution. In the smaller vessels or where smaller tanks are fitted due to a low water system, the grey water and sewage can be combined. The running costs would not change and the increase in liquid would still not be as much as the fuel consumed. In any event, the grey water is fresh water which is probably included in the vessel's deadweight and there is no added weight involved. Shore facility feed would increase due to the additional gallonage handled.

The cost of a tank for grey water can be obtained from Figure 25 in the same manner as the sewage tank but this time there would be no advantage to be gained from combining reduced water systems.

6.7 Summary of Costs

A summary of the cost of holding tank systems is shown in Table 7 for the typical laker and tug used in these guidelines. These costs are, in each case, based on the holding tanks recommended and show the comparison in costs when used in conjunction with low water, recirculating and flow-through systems.

The capital cost of installing a holding tank system at first glance seems rather high because, with a conventional water usage system, the volumes are high and the tank system has almost the same sub-systems as a flow-through treatment system. The capital cost in fact represents approximately 0.5% to 1% of the capital cost of the ship for the large ships and 1½% to 3% for the smaller vessels. The exception to these percentages is the fishing vessel in which the holding system may cost an amount equal to about 12% of the capital cost of the boat on the estimated figures.

It must be borne in mind, however, that the cost is that of a system to accomplish complete retention of sewage in order to protect our environment, and this is something on which it is difficult to put a dollar value. When the vast sums of money being spent by industry to comply with air, noise and water pollution throughout the work are considered, then perhaps the costs involved for the marine industry can be put in better perspective.

While it is not part of this study to recommend any system, other than offering design guidelines for the holding tank system, combining the holding tank with low water flow systems, recirculating systems

TYPE OF SYSTEM	COST ITEM	NEW CONSTRUCTION		RETROFIT	
		LAKER	TUG	LAKER	TUG
	CAPITAL COST OF SHIP	14,000,000	1,750,000		
HOLDING TANK SYSTEM (CONVENTIONAL WATER)	CAPITAL COST OF SYSTEM	74,100	23,600	81,510	28,320
	OPERATING COST PER YEAR	13,500	1,350	13,500	1,350
	MAINTENANCE COST PER YEAR	850	850	850	850
HOLDING TANK SYSTEM (WITH LOW WATER SYSTEM)	CAPITAL COST OF SYSTEMS	50,000	6,500	64,820	13,580
	OPERATING COST PER YEAR	1,800	450	1,800	450
	MAINTENANCE COST PER YEAR	1,000	1,000	1,000	1,000
HOLDING TANK SYSTEM (WITH RECIRC$^{\underline{N}}$ SYSTEM)	CAPITAL COST OF SYSTEMS	39,000	2,400	46,410	7,120
	OPERATING COST PER YEAR	900	450	900	450
	MAINTENANCE COST PER YEAR	1,000	1,000	1,000	1,000
HOLDING TANK SYSTEM WITH FLOW-THROUGH SYSTEM (CONVENTIONAL WATER)	CAPITAL COST OF SYSTEMS	110,000	25,000	117,410	29,720
	OPERATING COST PER YEAR	13,500	1,350	13,500	1,350
	MAINTENANCE COST PER YEAR	850	850	850	850
HOLDING TANK SYSTEM WITH FLOW-THROUGH SYSTEM (LOW WATER)	CAPITAL COST OF SYSTEMS	80,000	19,000	94,820	26,080
	OPERATING COST PER YEAR	1,800	450	1,800	450
	MAINTENANCE COST PER YEAR	1,850	1,850	1,850	1,850

TABLE 7 SUMMARY OF COSTS FOR HOLDING TANK SYSTEMS FOR TYPICAL LAKER AND TUG.

and flow-through treatment systems have been considered in order to ascertain the cost effect. The results of an approximate cost comparison indicate significant savings in capital costs and in pump out costs when combined with either the low water or recirculating systems, and it may well prove advisable for the ship owners to consider these systems. No saving in cost is apparent with the flow-through treatment systems but, of course, these systems have their own advantages over other systems, and each individual ship owner will have to carefully study the merits of each type of system before arriving at any decision.

Further reductions in both capital and operating costs may be obtained if the retention period is reduced from that indicated herein. Again, each individual ship owner will have to study the service of his vessel, and the availability of shore reception facilities before arriving at this decision, but is is strongly recommended that he follow the principles laid down in these guidelines and calculate his retention period allowing ample margin for delays.

Retrofit costs will range from 10% to 20% higher (20% to 30% when combined with a vacuum system) provided there are no major modifications to the existing structure or relocation of existing equipment and there is no loss in revenue-producing time while the conversion is carried out. Bearing in mind winter lay-up and a period of grace before any regulations come into force, there should be no problem in arranging for the work to suit this requirement.

Operating and maintenance costs have been estimated and are not unduly severe. Much of the cost involved is part of the normal watch-keeping costs of the ship, and it would be unreasonable to add them to the cost of the holding tank system.

While costs have been indicated for the retention of grey water, the means to calculate the tank size is given and the approximate cost can be otained from the tables and graphs for the sewage tanks. There is no doubt that the retention of grey water will add significantly to the cost of the vessel but the owner may prefer to pay, with the aim of obtaining complete retention which will comply with any possible future regulations.

DEFINITIONS AND DESCRIPTIONS

The following terms and abbreviations are used in this report:

Aerobic bacteria	- Bacteria that require free or dissolved oxygen or air for respiration, reproduction and growth. These micro-organisms break the bonds of organic compounds utilizing the energy derived for synthesis and leaving only inert oxidized by-products which do not give off offensive odours.
Anaerobic bacteria	- Bacteria that can respire, reproduce and grow in the absence of free or dissolved oxygen or air. They obtain oxygen by decomposing organic solids and some inorganic solids. Foul odours prevail when anaerobic conditions exist and these are due to the prescence of methane, hydrogen sulfide and other gaseous decomposition by-products.
BOD	- Biochemical Oxygen Demand (BOD) is the oxygen utilized in the stabilization of organic matter by micro-organisms under aerobic conditions. BOD is time and temperature dependent and the standard test is 5 days at 20°C. The results is often expressed as BOD_5. Under these conditions sewage will exert 65 to 70% of the total oxygen demand in the five day period. This is a test that will measure biologically oxidizable organic matter.
Body wastes	- Feces and urine discharged from the human body.
Comminution	- The process whereby shredding equipment is used to reduce large particles in the flow to a size suitable for handling in a holding tank or treatment unit.
Domestic Wastes	- Wastes entering the sanitary system from sinks, showers, laundries and galley (similar to grey water).

Effluent	- This means "flowing out" and usually refers to the contents discharged from a sewage holding tank or treatment device.
Flow-through Treatment System	- Flow-through treatment systems are biological systems using a device in which the sewage is treated and then discharged overboard, the effluent, after treatment, being of an approved standard. They can be anaerobic or aerobic systems but the anaerobic is not recommended. In these guidelines these systems are assumed to be of the extended aerobic type. The process involves comminution to break up the solids, aeration in the aeration compartment to stabilize the organic compounds, settling out the solids in the sedimentation compartment, draining off and disinfecting the clear liquid in the chlorination and holding tank before discharging an effluent which has minimal BOD, suspended solids and coliform bacteria.
Free Surface Effect	- The reduction in GM of the vessel due to the free movement of liquid in the tank.
Gallons	- Where gallons are mentioned throughout these guidelines they are to be read as Imperial gallons equal to 1.2 US gallons or 0.16/cu ft or 4.54 litres.
GM	- The vertical distance between the vessel's centre of gravity (G) and the metacentre (M); it is used as an indication of the stability of the vessel.
Grey Water	- Wastes from sinks, laundry and showers and liquid wastes unfit for drinking or bathing but potentially suitable for recirculation as a toilet or urinal flushing medium.
Hydraulic loading	- The quantity or volume of sanitary sewage entering a holding tank or treatment device during a specified period of time.

Pathogenic bacteria	- Disease-producing bacteria often present in sewage.
Recirculating Toilet or System	- A toilet or system (series of toilets and urinals) in which the flushing fluid is reused. This fluid often requires filtering (to remove solids), the addition of odour control chemicals, bleed-off and fresh water make-up or periodic disposal of the total spent fluid.
Retention System	- A system (which may be comprised of one or more holding tanks) in which wastes are retained prior to discharging to a shore reception facility or some treatment device.
Sewage	- Washes from toilets and urinals including flush waters, and any chemicals added.
Sludge	- The residue of settled solids which accumulates on the bottom of a holding tank.
Surge Loading	- Sudden and often short-lived increased hydraulic loading to the holding tank or treatment device.
Suspended Solids	- Solids either in or on a liquid that can be removed by filtering.
Vacuum System	- A toilet system (series of toilets and urinals) in which the flushing water is used only to clean the toilet or urinal bowl and re-establish a pool of water after use. The movement of sewage from the bowl to collection tank is achieved by maintaining a partial vacuum in the piping system and tank by means of a vacuum pump. Special toilets and urinals are required with rubber diaphragm type discharge valves. The system therefore results in a significant reduction of flushing water and is that system selected for these guidelines as a low water usage system. It is basically a retention system and provides no treatment of the sewage.

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APPENDIX I

MARKET REVIEW

Thirty-two (32) companies supplying sewage treatment systems to the marine industry in the U.S., Britain and here in Canada, were requested by letter to give information on holding tank equipment they would be prepared to supply.

Ten (10) companies replied.

Only two of the responding companies will supply a holding tank for a commercial vessel. One is supplied with comminution aeration sub-systems and one with comminution only although this manufacturer points out that each tank is custom built to owner requirements. One of the companies supplies small holding tanks for pleasure boats and the remaining companies either do not supply them at all, or supply them only as a part of their packaged sewage treatment system such as the vacuum type systems in which the holding tank is a pressure tank. One manufacturer supplies a conversion unit to assist in converting any existing system to a recirculating system and individual recirculating and vacuum toilets are readily available which will reduce the amount of water used and make holding for longer periods possible in small vessels. If "no discharge" regulations are made mandatory for certain areas, which would virtually mean that all ships in the Great Lakes will have to have some sewage holding capability,then obviously the market for holding tanks will be greatly increased which could move suppliers to manufacture them in the future. The varying capacities, pressure head and space available on different classes of ships are detrimental factors, however, which offset the attraction of the increased market, and it may well be that the space problem will be the deciding factor, as in too many vessels the tank may be custom built by a shipyard to suit the space available.

On the other hand, if the guidelines given in this report are accepted by both the marine industry and the governing authorities, then the suppliers will have a basis on which to devise a range of standard units which could be commercially acceptable to all concerned.

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COMPANIES CONTACTED

American Ship Building
400 Colorado Avenue,
Lorain, Ohio

Colt Industries (Canada) Ltd.
9125 Cote de Liesse Rd.
Dorval, Que.

Seapax, Inc., 1898 Carter Road.,
1898 Cleveland, Ohio 44113

Micropher Inc.,
Willits, California, U.S.A.

Chrysler Corporation, Space Div.
New Orleans, Louisiana, U.S.A.

Zurn Industries,
1801 Pittsburg St., Erie, Pa

Wilcox-Crittenden, 699 Middle St.
Middletown, Conn

Raritan Engineering Co.
Milville, New Jersey

Valdespino Laboratories,
Orlando, Florida

Electronics & Systems, Inc.
Lundy Electronics, Glen Head, N.Y.

Fifer Industries,
Louiseville, Kentucky

Fram Corporation, 2929 E. Apache,
Tulsa, Oklahoma

Jered Industries Inc.,
1300 Collidge Road,
Birmingham, Mich. 48008

Peacock Bros. Ltd. Pump & Apparatus
P.O. Box 1040, Montreal, Que.

W. Cockram & Co. Ltd., 100 Walnut St.
Paris, Ontario.

Litton K-D Dept. MSTS, P.O. Box 309
South St., New Britain, Conn. 06050

Aquanox, Inc. Fairwater Sales Ltd.,
5175 de Maisonneuve, Montreal, P.Q.

Pacific Coast Plastics Ltd.,
139 Riverside Drive., North Vancouver,
B.C.

Demco Inc., 845 S.E. 29th Street,
Oklama City, Oklahoma

General American Transportation Corp.
Niles, Illinois, U.S.A.

Westinghouse Electric Corp.,
Infilco Div., 401 E. Main St.,
Richmond, Virginia, U.S.A.

American Ship Building Co.
400 Colorado Ave., Lorain, Ohio

Bio - Pure, Tulstin, Oregon, U.S.A.

Brabazon Associates of Can. Ltd.
925 Mooney, Ottawa, Ontario

Vacusan Systems Ltd.,
375 Ormont Drive, Weston, Ont.

Hamworthy Canada Ltd.
11275 Cote de Liesse Rd.
Pointe Claire, Que.

John Misener Marine Equipment Ltd.,
Box 278, Marine Rd. Port Colborne, Ont.

Marine & Power Equipment Ltd.
150 Grande-Cote, Rosemere, Quebec

General Electric Co. (Environmental
Div.) 3198 Chestnut Street,
Philadelphia, Pa.

Pall (Can)Limitée, B. Postale 370
Saint-Laurent, P.Q.

Wilson Water Purification Corp.
2371 Broadway, Buffalo, New York.

APPENDIX II

STABILITY CALCULATIONS

To determine the effect on static stability for the vessels used as typical of their respective classes in the preparation of these guidelines, assumptions have been made based on our experience, and stability calculations carried out based on these parameters.

A summation of the results is given in Tables 8 and 9 showing that for normal installations, the free surface effect of holding tanks on stability is negligible. With tanks placed in certain locations it can be seen that the result is an increase of statical stability.

Pages 91 and 92 blank

VESSEL TYPE	L	B	D	H	INITIAL					HOLDING TK CAPACITY		TANK VCG	TANK DIMENSION			F–S MON'T FT.TONS	FINAL					% CHANGE G.M.
					Δ_1	KB_1	BM_1	KG_1	GM_1	GALLS	TONS		A	B	C		Δ_2	KB_2	BM_2	KG_2	GM_2	
TUG	100	28·5	15·4	12·14	450	7·7	8·0	12·5	3·2	4000	13	6·0	11	8	8	13·0	463	7·82	7·78	12·35	3·25	+1·6
WATER-BUS	70	22	9	4·5	95	2·7	9·3	8·0	4·0	900	3·6	4·0	8	4	5	1·2	98·6	2·77	8·96	7·87	3·86	−3·5
LARGE DREDGER	222	45	19	15·5	3590	7·85	9·15	12·8	4·2	2 X 7500	56	6·5	14	10	10	65·0	3646	7·97	4·01	12·72	4·26	+1·4
SMALL DREDGER	65	16	5	3·5	88	1·84	5·36	5·0	2·2	500	1·9	3·0	7	3	4	0·4	89·9	1·87	5·26	4·96	2·17	−1·4
TANKER	370	54	26·5	21·0	9830	10·75	10·50	18·55	2·7	2 X 7500	56	13·5	14	10	10	65·0	9886	10·81	10·44	18·53	2·72	+0·7
LAKER	675	75	45·8	30·0	38412	15·8	13·3	26·3	2·8	2 X 7500	56	6·0	14	10	10	65·0	38468	15·82	13·28	26·27	2·83	+1·1
FISHING VESSEL	70	19	10	6·52	107	3·82	6·46	8·38	1·9	400	1·9	5·8	6	4	3	0·9	108·9	3·86	6·36	8·34	1·88	−1·1
FERRY	296	64	21	13·5	4114	7·8	23·5	25·2	6·1	10,000	32	6·0	18	10	10	41·7	4146	7·84	23·32	25·08	6·10	0

TABLE 8 CONVENTIONAL WATER USAGE HOLDING TANK EFFECT ON STATIC STABILITY

VESSEL TYPE	L	B	D	H	INITIAL					HOLDING TK CAPACITY		TANK VCG	TANK DIMENSION			F – S MOM'T	FINAL					% CHANGE
					A_1	KB_1	BM_1	KG_1	GM_1	GALL^S	TONS		A	B	C	FT.TONS	Δ_2	KB_2	BM_2	KG_2	GM_2	G.M.
TUG	100	28·5	15·4	12·14	450	7·7	8·0	12·5	3·2	400	1·3	6·0	6	4	3	0·9	451·3	7·71	7·98	12·48	3·21	+0·3
WATER-BUS	70	22	9	4·5	95	2·7	9·3	8·0	4·0	100	0·4	4·0	3	3	2	0·2	95·4	2·71	9·26	7·99	3·98	−0·5
LARGE DREDGER	222	45	19	15·5	3590	7·85	9·15	12·8	4·2	2000	5·6	6·5	10	6	6	5·0	35956	7·86	9·14	12·79	4·21	+·2
SMALL DREDGER	65	16	5	3·5	88	1·84	5·36	5·0	2·2	100	0·2	3·0	3	3	2	0·2	88·2	1·84	5·35	5·00	2·19	−1·4
TANKER	370	54	26·5	21·0	9830	10·75	10·50	18·65	2·7	2000	5·6	13·5	10	6	6	5·0	98356	10·78	10·49	18·65	2·70	0
LAKER	675	75	45·8	30·0	38412	15·6	13·3	26·3	2·8	2000	5·6	6·0	10	6	6	5·0	38418	15·80	13·30	26·30	2·80	0
FISHING VESSEL	70	19	10	6·52	107	3·82	6·46	8·38	1·9	100	0·2	5·8	3	3	2	0·2	107·2	3·83	6·45	8·38	1·90	0
FERRY	296	64	21	13·5	4114	7·8	23·5	25·2	6·1	900	3·2	6·0	8	4	5	1·2	41172	7·80	23·48	25·19	6·09	−0·2

TABLE 9 LOW WATER USAGE HOLDING TANK EFFECT ON STATIC STABILITY

APPENDIX III

COST CALCULATIONS FOR HOLDING TANKS

The capital cost of the installed holding tanks was estimated for different sizes of tanks and a typical estimate is given here for the 1000 gallons size tank.

All such figures were plotted and faired curves drawn to give the approximate average costs for any size tank up to 10,000 gallons.

Pages 96 thru 98 blank

COST ESTIMATE FOR 1000 GALLONS TANK

1) BASIC TANK WITH PUMPS, VALVES, PIPING & ELECTRICAL WORK

Steelwork: 1.66 tons at $2000 per ton		$3320.
Installation:		400.
Painting:		
Inside - 184 sq ft at 10 cents sq ft shop blasting.	18.4	
NUPLATE A 3/4 gal at $7 gal.	5.2	
INTERTAR 4½ gals at $10 gal.	45.0	
Outside - 184 sq ft at 15 cents sq ft wire brushing.	27.6	
NUPLATE A 3/4 gal at $7 gal.	5.2	
LAGOLINE 1¼ gal at $7 gal.	8.8	
Labour - 3½ hours at $10/hr.	35.0	
	145.2	145.
Piping & Pumps		
2 pumps 33 gpm at 60 ft head	1200.	
Valves 3 - 4"	300.	
8 - 3"	450.	
2 - 2"	50.	
2 - Solenoid	50.	
Piping & Fittings including exhaust Vent and flushing	550.	
Instrumentation	405.	
Labour, 120 hr at $10/hr.	1200.	
	4205.	4205.
Electrical:		
Material - wiring, trays Starters, etc.	2000.	
Labour 150 x $10/hr.	1500.	3500.
	TOTAL	$ 11570.

COST ESTIMATE FOR 1000 GALLONS TANK (CONT'D)

2) ADDITIONAL COST FOR COMMINUTION

4" Comminutor:	1800.
Installation and electrical:	500.
TOTAL $	2300.

3) ADDITIONAL COST FOR AERATION

Compressor 100 CFM 0 - 6 psi:	450.
Piping and Fitting:	450.
Electrical:	500.
Installation:	650.
TOTAL $	2000.

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